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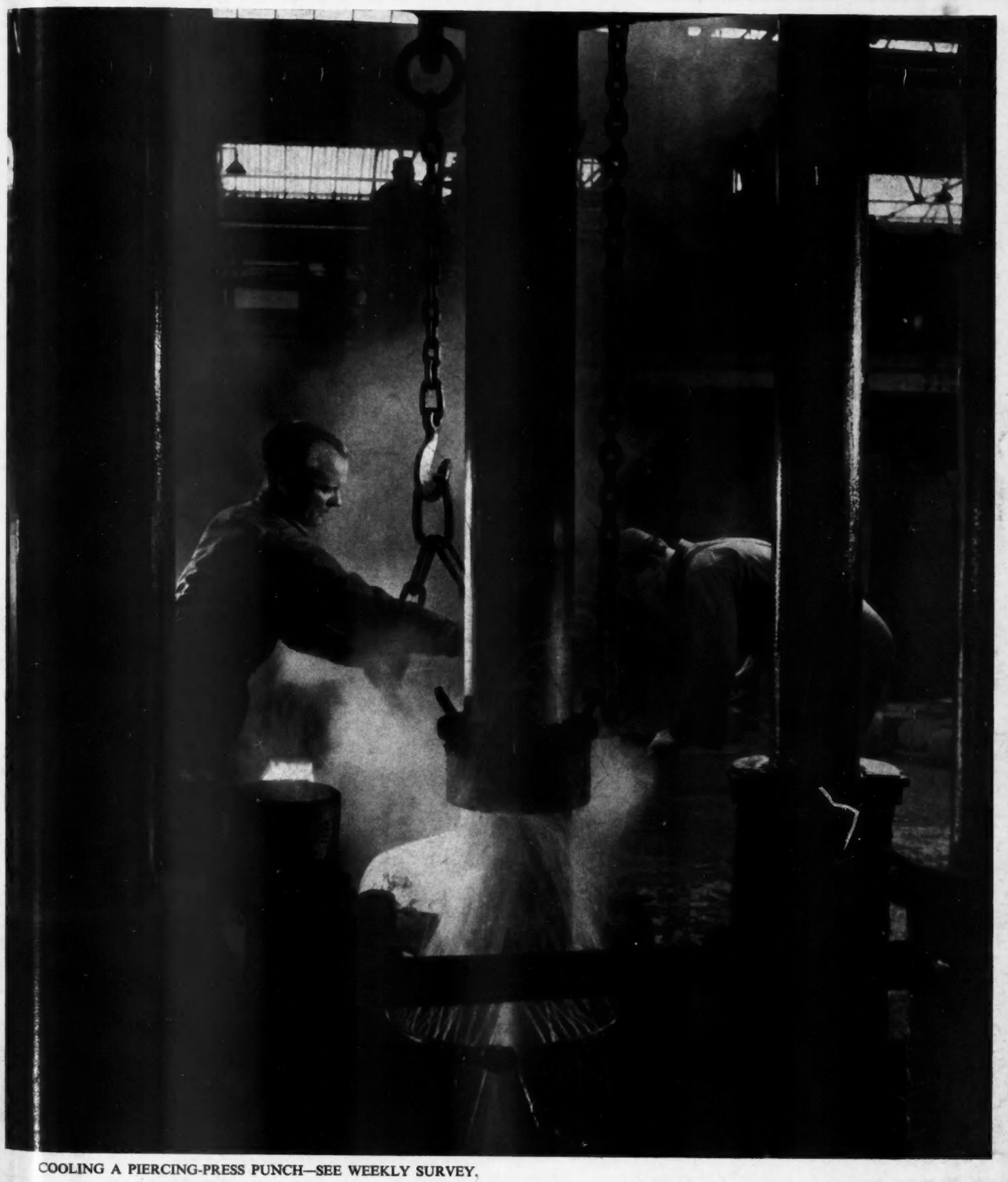

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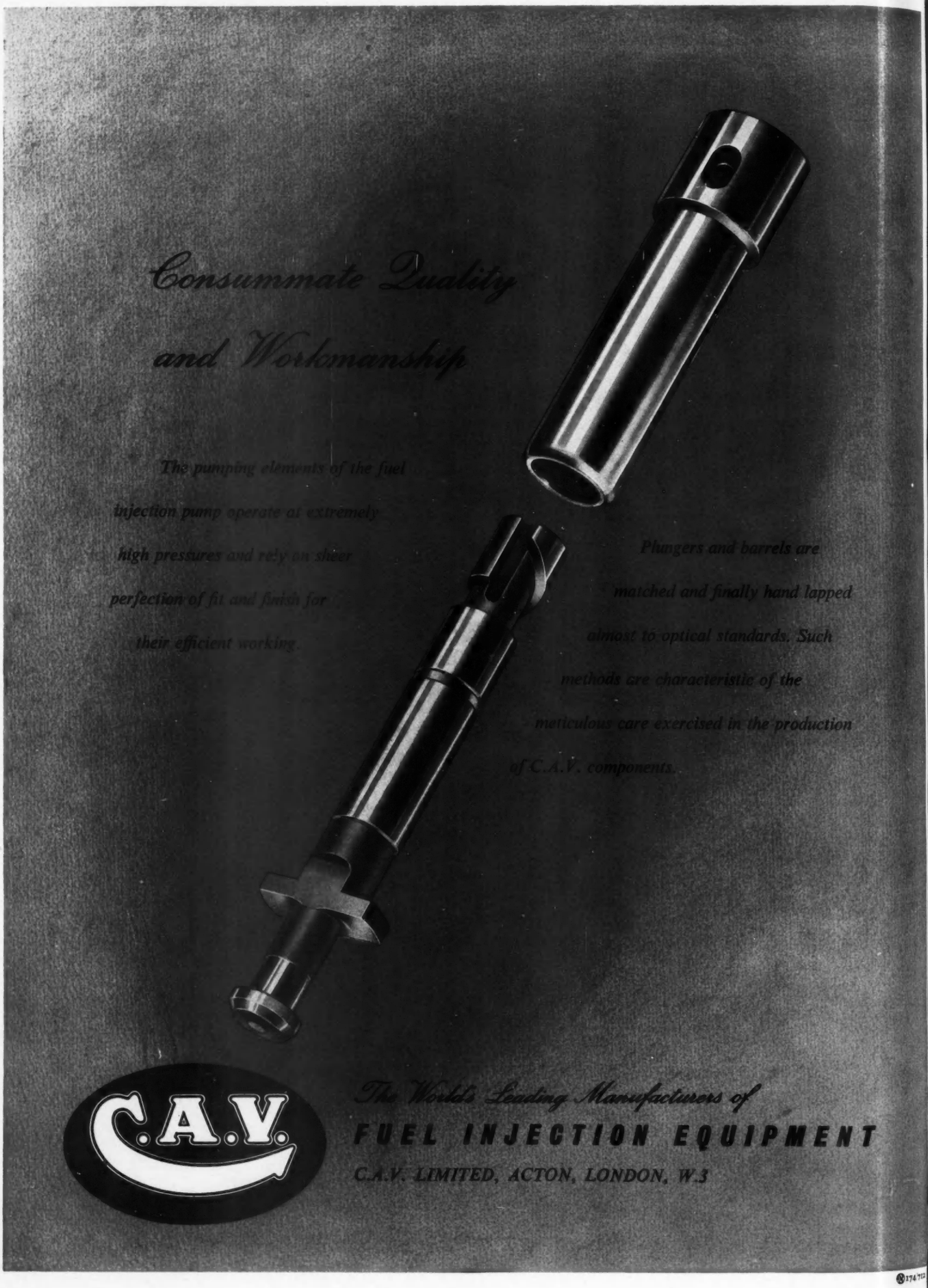
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HELP FROM THE COLLEGES

It is a common experience to-day for a man to have more work to do than he can reasonably hope to cope with; or perhaps it would be more accurate to say that he has no difficulty in discovering avenues of inquiry which he would enjoy exploring but which, alas!, he can never tread. Fuel experts may tell him that science and engineering are providing him and his wife, and his children, with the equivalent of 15 or 20 slaves each, but he can as well reply that he is carrying a burden equivalent to several pieces from an aircraft, a gun and a battleship, not to mention quite a load of paper.

Many engineers—and firms—who find themselves overloaded with work often have to confine their interests to a restricted field in order to avoid a wasteful dispersal of effort. Thus, for example, not every firm which has been successful in the development of gas-turbines has devoted some of its resources to the industrial applications of gas-turbines. Better by far to succeed in, say, the aircraft applications and not attempt the other, than to achieve only partial success in both.

We received a letter last week from an old friend who is now chief engineer to his firm. "I never seem to get time," he protested, "to sit back and take a long-term view." Under those conditions, questions of immediate importance are attended to but most of the remainder are shelved. And one that is almost certain to be neglected is the improvement of design and production by means of research and development. Yet here, if anywhere, it is possible to use outside help. The Institution of Mechanical Engineers are devoting their Friday evening meeting in London on January 28 to a discussion on "Co-operation in Engineering Research between Educational Institutions and Industry." It is surprising what scope there still is for liaison between engineering firms and colleges. Hitherto, there has been a tendency to think of this kind of co-operation in terms of the universities, a few large technical colleges and the larger companies. But in fact it is often the small or medium-size firm which, by using personal contacts, can make good use of such supplementary facilities as local technical colleges.

The discussion on January 28 will be started by three prepared papers, written by Professor E. Giffen, Mr. V. C. Davies, and Mr. J. H. R. Nixon. According to the January issue of *The Chartered Mechanical Engineer*, Professor Giffen will advocate increased co-operation in research as being beneficial to both industry and the universities. Some of the problems associated with such an increase, he argues, could be solved by full and frank discussion by all concerned, and any arrangements for co-operation in research should be based on a rate of expenditure large enough to ensure a reasonable rate of progress. Professor Giffen is Dean of the Faculty of Engineering in London University.

Mr. V. C. Davies, after long experience in teaching engineering, is now supervisor of research in the Department of Civil and Mechanical Engineering at the Battersea Polytechnic. He points out that the higher technical college can assist industrial research by (1) training suitable students in research methods so that they can fill positions in an industrial research department; and (2) itself carrying out research work of importance to industry either by its staff or by students in training. The higher technical college can also provide for the part-time research worker. As Mr. Davies remarks, many men with marked ability for research cannot afford the cost of spending two years of full-time study, or may feel that the industrial experience they are gaining simultaneously may be more than worth-while. A part-time student, he says, can get through a surprising amount of work, especially when he is encouraged by his employers.

The third speaker, Mr. J. H. R. Nixon, is technical director at the Loughborough Works of the Brush Electrical Engineering Company. He will emphasise the value of contacts between engineers in industry and those engaged in education as a means of developing more research. "There is evidence," he writes, "that the mechanical engineering industry is lagging behind some other industries in this respect." If the evidence is the report entitled "Applied Research in Technical Colleges," published last year by the London and Home Counties Regional Advisory Council for Higher Technological Education, it should be viewed with caution. This report lists "original papers . . . appearing in journals or transactions of learned societies by the staff and/or students of technical colleges. . . . The list is confined to papers which contribute new knowledge to science and technology. It does not include articles and reviews contributed to the scientific and technical Press . . . ." The omission of the latter category—many of which certainly contribute new knowledge—results in a list which gives undue prominence to chemistry and very little mention of engineering.

The discussion, if it is to bear fruit, should concentrate on the means of increasing the number of cases where a college does some useful work for an engineering firm. The desirability of such an increase will be generally accepted. How can it be achieved?

Weekly Survey

Cover Picture: *Increasing quantities of oxygen, hydrogen, acetylene and other gasses are consumed in many industrial processes, and the compressed-gas cylinder is a familiar sight in the shops of works engaged in all branches of engineering. The cover illustration shows a stage in the manufacture of seamless steel tubes and cylinders for industrial gasses—the cooling of the punch of a vertical press used for piercing the solid billets.*

* * *

LABOUR IN ENGINEERING

The current year, like 1954, is so far one of full employment in the engineering industry, but as the article in the Engineering Outlook series on page 73 points out, there are some very fundamental labour problems to be solved. The Confederation of Shipbuilding and Engineering Unions have felt justified by the continuing prosperity to put forward a claim for an increase in wages, and this raises not only the question of the industry's ability to meet such a demand but also that of maintaining differentials between different grades of labour. The industry's ability to meet a higher wages bill must depend upon the achievement of higher productivity, which in turn requires increased investment in plant and machinery. Unfortunately, the amount invested each year per worker by British industry is still unduly low, although as a result of the incentives in the 1954 Budget there should be a noticeable improvement this year.

The limited resources of the United Kingdom make it inevitable that progress should be slow. It is not, in any case, desirable that British investment should be on the American scale. British manufacturers can seldom command the mass market which makes large-scale production (and investment) possible in the United States, and British solvency still depends to a marked extent upon the ability of the craftsman to build products which will suit the individual requirements of a large number of foreign markets. In the United States, of course, some of the incentive to investment derives from the high level of wages. Wages agreements are often based on the assumption that productivity will rise at the rate of 2½ per cent. per annum, which means that employers can only meet their commitments by increased mechanisation. In the United Kingdom, both employers and workers are now showing increasing awareness of the mutual relationship between wages and productivity, but there are still many practical difficulties in the way of a satisfactory wages policy.

Wage agreements negotiated on the national level cannot easily take account of the varying conditions in different sections of the engineering industry, and in different parts of the country. The motor-vehicle industry, for example, which is investing very large sums, can obviously support a much higher level of wages than the more traditional sections of the engineering industry. Labour in the more mechanised industries, moreover, does not fall easily into the traditional gradings of skill. An adequate solution of these problems will require nothing short of a radical overhaul of the wages structure of the engineering industry. This was recommended by a Court of Inquiry as long ago as 1948, but although the need has become increasingly apparent little has so far been done. Fortunately, there is evidence in the present wages claim of a desire from the unions for a revised wages structure. They have suggested the establishment of three or five intermediate grades (in addition to the accepted skilled and labouring grades) to provide for the growing groups of men who have acquired a certain kind of skill as mechanisation has increased.

* * *

BRITISH SHIPBUILDING

At the launch of the Esso Exeter on January 5, Mr. G. H. Houlden, general manager of Vickers-Armstrongs' Naval Yard, drew attention to the fact that the shipbuilding industry's order book has been steadily running down during the past year. In some quarters this has given rise to considerable anxiety regarding the future of the industry, but Mr. Houlden appears to share the view expressed in our Weekly Survey for November 19 that there is as yet no serious anxiety among British shipbuilders.

The tonnage of merchant ships completed in British shipyards in 1954 was more than 1·5 million gross tons, the highest figure recorded since the war, due mainly to the improvement in steel supplies. During the year new orders totalled about 600,000 tons but these were partly offset by cancellations amounting to 300,000 tons. The net result has been to reduce the orders on hand from a peak of about 7 million tons in 1952 to 4¼ million tons at the end of 1954. There was some improvement in the placing of new orders in the last three months of the year, but since, even at the reduced level of orders, few British yards can offer delivery before 1957 and would scarcely be justiffed in quoting a fixed price so far ahead, there will be no immediate cause for anxiety if ordering on a substantial scale is deferred for a further six months.

Foreign countries have benefited from the congestion in British yards. Germany, now the second largest shipbuilding nation, had a record year with an output of 925,212 gross tons. Orders on hand are estimated at 1·3 million gross tons, which is 10 per cent. less than a year ago but 18 per cent. more than in July, 1954.

Of vessels of 1,600 tons and over, tankers account for a high proportion of the total tonnage completed in British yards, the proportion being 58·5 per cent. in 1953 and 52 per cent. in the first eleven months of 1954. This year the launching of the Esso Exeter referred to above was followed by that of the Royal Dutch Shell Vexilla at Birkenhead. This is the first of six 31,000-ton oil tankers being built for the company in the United Kingdom. At the launching, Mr. J. W. Platt, a managing director of the Royal Dutch Shell group, referred to the company's intention to adopt gas-turbine propulsion, and further details of this proposal are given in the following Weekly Survey note. Moreover, Mr. A. F. Hull, chairman of the Ellerman and Bucknell Steamship Company, has stated that the gas-turbine marine engine, if found successful over the next few years, should prove substantially cheaper than existing methods of propulsion, both in first cost and in operating expenses. This development might well provide the stimulus required to induce shipowners to increase their orders for new tonnage.

* * *

THE GAS TURBINE AND MARINE PROPULSION

When Mr. J. W. Platt, a managing director of the Royal Dutch/Shell group, discussed the future of ship propulsion at the launching of the tanker Vexilla on January 11, he drew attention to a major advantage of the gas turbine. " Wear and tear in any piece of machinery," he said, " is materially due to vibration and to reciprocating motion. If it is possible to substitute simple rotary motion, the machine must surely last longer and need less attention and repair. Already our experience has established that the gas turbine is vibration-free and, even more, that it tends to damp vibration from other sources."

Mr. Platt also considered that existing forms of ship machinery did not offer the same scope for improvements in fuel economy and reductions in plant size and weight as the gas turbine, and it was with these considerations in mind that his company had decided to employ the 12,000-ton tanker Auris as an experimental vessel in the field of gas-turbine propulsion. The Auris, which had been the first merchant ship to be fitted with machinery of this kind, had been a source of valuable experience.

In 1949 a gas-turbine alternator unit, made by the British Thomson-Houston Company, had been installed in place of one of the Auris four Diesel engines (ENGINEERING, vol. 171, pag 209, 1951) and since that time it had operated under severe sea conditions for 13,000 hours without mechanical fault. Now it was proposed that all the present propulsion machinery should be stripped from the Auris and replaced by a single 5,500-h.p. gas-turbine engine, also built by the B.T.H. Company. In addition, the problem of direct mechanical transmission was to be studied, and a form of direct gearing coupled to a fixed propeller was being designed.

Reference was made to the Auris' original gas-turbine plant in a paper entitled " The Choice between Single and Multi-Combustion Systems for Gas Turbines " delivered by I. G. Bowen, B.Sc., and W. Tipler, M.A., to the N.E. Coast Institution of Engineers and Shipbuilders on January 14. In this paper the authors examined the influence exerted by the choice of combustion system on overall design and layout of engines, and on the design of component combustion chambers. Their principal conclusion was to favour in general the use of a minimum number of combustion chambers, especially for units burning residual-type fuel oil. It was considered that the additional space required for a single-chamber engine was amply justified by its reliability and simplicity of operation.

In any case, whatever combustion system is adopted for a particular engine and whatever general developments in gas-turbine design may take place, there can be little doubt that the future of this prime mover is assured. Addressing the London branch of the Chartered Institute of Secretaries, Mr. A. F. Hull, in the speech mentioned in the preceding Weekly Survey note, recognised the need for a form of propulsion cheap to install and economical to run and wondered if the gas turbine would provide an answer. He said: " We shall know during the next seven gears. If it is a success when applied to marine engines—and I think it will be—then in a short time the steam turbine and the Diesel motor will be as obsolete as sail."

* * *

A RECORD BUT . . .

Exports finished 1954 with a spurt of 30 per cent. over the level in November, which had been adversely affected by the dock strike. The increase last month was sufficient to offset the November decline and to make the monthly average for the fourth quarter of the year very near to the averages in the first three-quarters of the year, which were all remarkably close together. Over the year as a whole, United Kingdom exports totalled £2,674 million, which was the highest level ever reached both in value and in volume. Imports for the whole of 1954 totalled £3,383 million, which was 1 per cent. more than in 1953. The excess of imports over exports was £609 million, compared with £655 million the year before. It is therefore likely that the visible adverse trade balance for the year will turn out to be notably smaller than in 1953. It would be dangerous to put it more strongly than this at present, for the month-to-month trade returns are notoriously misleading on the state of the visible balance.

Towards this large increase in last year's export trade, engineering goods made a substantial contribution. Exports of vehicles, aircraft and ships were particularly satisfactory and only one major category, namely electrical machinery, was less buoyant than in 1953. Such, indeed, seems to be the outcome on the year, to judge from the first 11 months' results. December figures for engineering categories are not yet available.

The very satisfactory level of exports compared with 1953 should not obscure the fact that other countries have been doing even better, and that the challenge from Germany and Japan is particularly severe on price, delivery and quality in some engineering markets abroad. The fact

that exports of electrical machinery have tended to lag could mean that competition from Germany is becoming increasingly strong in this category. Until comparatively recently this was one of the engineering groups in which the United Kingdom was maintaining a useful lead. The importance in the export market of delivering the right quality and goods of the right price will not become less in the current year, a point which the chairman of Martins Bank made in his annual address, which as usual opens up the season of commentaries on current affairs delivered by the chairmen of the leading banks.

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THESE COMPLICATED AIRCRAFT

The conference on aircraft production which the Institution of Production Engineers inaugurated three years ago appears to be developing its own tradition of bringing out into the open the weak points of the aircraft industry. Last year the chief engineer of British European Airways called attention to some of the less desirable features that he had encountered in British air liners. This year two viewpoints on military aircraft were put forward which might well become subjects for nation-wide discussion.

As reported elsewhere in this issue, the principal director of aircraft research and development at the Ministry of Supply, Mr. Woodward-Nutt, has suggested that the ever-increasing cost and complexity of military aircraft will drastically limit the numbers that can be ordered. "In other words," he said, "military aircraft in future are more likely to be ordered in tens than in hundreds or thousands." Great Britain is, then, to commit the safeguarding of her air security to a handful of machines which may or may not be superior to the enemy's, and for which replacements cannot be quickly made available.

The other point of contention, raised by two speakers—Mr. W. E. W. Petter, managing director of Folland Aircraft Limited, in his concluding talk, and Professor E. J. Richards in the discussion, is that the British aircraft industry is trying to design too many aircraft; that there are simply not enough men in the country with the requisite qualities of leadership, inventiveness and diplomacy to carry through the projects now in hand. Both speakers agreed that neither nationalisation nor the swallowing-up of the smaller firms by the large ones would provide a solution. Mr. Petter "sees nothing but ossification arising from the attempt" to merge the administration machinery of the customers, the industry and the co-ordinating supply ministry. There are, he suggests, weaknesses in all three which must be eradicated; a tendency for the customer to frame over-ambitious requirements, over-commitment on the part of the customer, and a lack of effectiveness on the part of the Ministry of Supply in balancing the claims of customer and industry.

The difficulties of supersonic flight, and the time to develop new radar and weapons had been underestimated, and the tendency had been to aim too far ahead, thereby reducing the chances of successfully developing the combination of aircraft, weapon and guidance equipment and of attaining the target date. There were now, however, signs that a policy of shorter steps was finding favour.

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MOTOR CARS—

The plans announced last September by Mr. Harlow H. Curtice, President of General Motors Corporation, provide for the doubling of Vauxhall's 1954 output of cars and trucks within five years. The expansion scheme, which is to cost £56 million, will entail an increase of 3 million sq. ft. divided about equally between the Luton and Dunstable factories. The latter will become the Bedford-truck production unit and Luton will concentrate on the manufacture of cars; 14,500 people are already employed at Luton and this number will be maintained, but more operatives will eventually be required at Dunstable. Vauxhall state that when the present expansion scheme is completed their manufacturing facilities will be "among the most up-to-date in Europe."

Most of the motor industry's planned expansion during the next five years has now been announced. The schemes will raise British output to about 1½ million vehicles a year, of which just over a million will be cars. This represents an increase of approximately 50 per cent. on the 1954 output of vehicles, which for the first time in the industry's history has exceeded the million. Total investment is likely to be £200 million at an average rate of £40 million a year. The implications of such a large expansion are yet to be fully worked out, but it is clear that it will have a major impact on British engineering as a whole and more particularly on the iron and steel industry (see last week's article: "Another Wide Strip Mill ?"). Quite apart from increased requirements for steel, bearings and other components, there will be a need for more workers and it is difficult at this stage to see how this will be met, except from industry in the vicinity of the works of motor vehicle and motor-vehicle components manufacturers.

The expansion of Vauxhall Motors is considerably greater than that envisaged by the industry as a whole—an increase in output of 100 per cent. compared with an overall increase of 50 per cent. This is clear evidence that General Motors have complete confidence in the expansion of motor-vehicle demand in the sterling area and Europe. They have also planned a considerable expansion in the output of their German plant at Rüsselsheim, where Opel are increasing their output of vehicles to 1,000 a day. This means that within five years General Motors will be producing over 2,000 vehicles a day in Europe and, in addition, assembling Canadian and American-built vehicles in Belgium, Denmark and other countries.

—AND MOTOR-CAR COMPONENTS

The high level of activity in the motor industry is putting a heavy load on manufacturers of motor-vehicle components, among whom some of the most important are the Associated Engineering Holdings group of companies. At the annual general meeting last week the chairman of the parent company, Mr. A. H. Jarrard, stated that all the companies had a heavy forward order load and that the advertised expansion plans of the motor and engine manufacturers would call for a considerable increase in the production capacity of the manufacturers of components.

The chairman of the Midland Regional Board for Industry stated in December that the motor industry had approached its suppliers to step up their output in proportion to its own production increases and that rather over £100 million would be spent by component manufacturers on capital expenditure to increase production and productivity. This figure referred to Great Britain as a whole but it was expected that a large percentage would relate to the Midland region. Some strain is already being felt by the labour resources of the Midlands; in November there were 47,000 vacant jobs in the area and 10,400 unemployed out of an insured population of 2 million.

The A.E.H. group of companies, of course, also have important interests outside the motor industry. The chairman referred to a new line started by the Wellworthy Company, with Ricardo & Company, Engineers (1927) Limited: the manufacture of a piston-type compressor for supercharging Diesel engines, and stated that the company were constantly on the look-out for new products. One field in particular in which the company may expect a substantial increase in demand is the manufacture of gas-turbine blades in view of the growing interest in the gas-turbine referred to elsewhere in these notes. In view of this increased demand the company has purchased additional land adjoining their Yeadon works and erected a new building in which production has just begun.

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TUBE PRODUCTION

One of the interesting features in the accounts of Stewarts and Lloyds which have just been issued to its new shareholders—new in the sense that the company is now operating under free enterprise again—is the growth in the fixed assets. These show that there was in the period under review a gross capital formation before depreciation of almost £9 million, which reflects to a large extent the expansion of the plants at Corby and on Clydeside. The impressive recovery in Stewarts and Lloyds' export business from its Scottish works over the last 15 years has owed a great deal to the continued expansion of the world oil industry. Though the main impact of prosperity from this source has been on the Scottish works of the company, the huge plant at Corby has also benefited, although welded tubes from this works have a rather more diversified outlet than the seamless tubes made farther North. The general prosperity in tube and pipe making which has overtaken Stewarts and Lloyds has, of course, equally helped Tube Investments, the other large tube manufacturers in the United Kingdom.

The scope which exists for tubes in the oil industry, notably in casings for oilwells and transportation, is seen in the 5¼ million dols. contract obtained by Stewarts and Lloyds (payable in dollars) to supply 490 miles of line pipe to the U.S. military bases in Spain. So long as military installations of this kind are being built, there must be a demand for piping. This, however, is in addition to the expansion in the world oil industry and to the rapidly growing outlet for tubes of all kinds in the extraction and transportation of natural gas.

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RAILWAY ELECTRIFICATION NOW?

The Institution of Electrical Engineers spring two surprises this month. The *Journal* has been completely redesigned in typography and layout and it contains an outspoken article on railway electrification in Britain, written by the chairman of the Institution's Traction Technical Committee. "Why is electrification so slow?" he asks, "Not because of material reasons, but patently owing to a lack hitherto of imagination and forceful enterprise, which should no longer be tolerated by the British people."

The steam locomotive, he argues, is apparently incapable of any further substantial improvement and must give way to other more efficient and modern forms of motive power. He instances the railways of Switzerland, Sweden, the Netherlands, Italy and France as evidence of the economic value of electrification. In Britain the Southern Railway embarked on a large programme of electrification in the period 1925-1939, but since the war "only two schemes have been inaugurated"—the Liverpool Street-Shenfield and the Manchester-Sheffield-Wath lines (both authorised as far back as 1936). "It is amazing that Britain, an electrically-minded nation, is so far behind contemporary thought on electric traction."

The chairman of the Traction Technical Committee is well qualified to put the case for large-scale electrification of British Railways. Before joining the English Electric Company in 1950 Mr. C. M. Cock was Chief Electrical Engineer to the Railway Executive. A note at the end of his article states "Not every member of the Traction Technical Committee endorses this article in its entirety." There can, however, be little argument over his call for action. The main points are familiar—greater thermal efficiency; a transition from smoke and dirt to cleanliness and brightness; improved conditions for the driver, and so on. He gives an assurance on the ability of British industry to undertake the work, and he believes that there would be no difficulty in raising capital.

Conference on Problems of Aircraft Production

AIRCRAFT DESIGN PROBLEMS AND TRENDS

The use of large machined forgings or slabs for the main components of airframes—known as " integral " or " integrated " construction—contrasted with traditional built-up structures, was nominally the subject chosen for the third Aircraft Production Conference held by the Institution of Production Engineers at the University of Southampton on January 14 and 15. In fact, only the first lecturer, Mr. A. E. Woodward-Nutt, Principal Director of Research and Development (Aircraft), Ministry of Supply, discussed the pros and cons of integral construction in his talk on " Aircraft Design Problems and Trends ". In the discussion which followed this paper, it was clear that the majority of the speakers were convinced of the necessity for changing over to integral-construction methods for building the high-speed aircraft of the immediate future.

Of the other four papers presented, three were concerned with developing the techniques of integral construction—" Problems of Forging," presented by Mr. G. W. Richards (director of High Duty Alloys Limited) ; " Machining and Forming Problems of Integral Construction," by Mr. E. D. Keen (assistant chief designer), and Mr. A. Menzies (process development manager Sir W. G. Armstrong Whitworth Aircraft, Limited) and " High Speed Machine Tools for Aircraft Production," by Mr. S. Radcliffe (works director, Wadkin Limited), who spoke on behalf of the Machine Tool Trades Association.

The final paper, entitled " Where Do We Go From Here?" by Mr. W. E. W. Petter (managing director, Folland Aircraft, Limited), after a brief summing up of the conference, was devoted to a general appraisement of the effectiveness of the aircraft industry, and is referred to elsewhere in this issue.

INCREASING COMPLEXITY

How the growing cost and complexity of aircraft is likely to affect constructional methods was the theme of Mr. Woodward-Nutt's paper. Discussing the evolution of the aircraft structure, the lecturer said that the desire to spread the steadily-increasing flight loads more evenly over the wing and fuselage surfaces had led in the 1940's to multi-spar or torsion-box wings and fuselages of stressed-skin construction. Performance increases had demanded thinner, smoother, and eventually swept-back wings. Now the tendency was to employ still thinner wings with relatively thicker skins which lent themselves to more integrated construction.

At the same time, aircraft had become heavier and more complex. Over the past 40 years, the weight of a fighter aircraft had increased roughly 20 times and that of a bomber 10 times. It was interesting to speculate whether the advent of nuclear weapons would arrest this trend in the bomber. At the start of the 1939 war fighter aircraft cost about £7,500 each, and bombers about £20,000. To-day, fighters in current production cost nearly £100,000 each, and those of the next generation were likely to cost more than double this figure. Current bombers and military transport cost about £500,000 each, and future types were likely to exceed this figure considerably.

Mr. Woodward-Nutt then quoted several examples of increasing complexity in design and equipment. In a current single-engine day fighter aircraft, he observed, there were nearly 250,000 rivets and over 35,000 nuts, bolts and washers, amounting to a total weight of nearly 950 lb.

FEWER MILITARY AIRCRAFT

One conclusion to be drawn from this picture was that any method of construction that would reduce cost and complexity deserved study. Another conclusion was that, since there was unlikely to be any substantial increase in the amount of money available for purchasing new military aircraft, the numbers ordered in the future were likely to be far less. This had a direct bearing on the possible capital investment in equipment and tools for their manufacture.

Although the " shape of wings to come " was still problematical, it was certain that at the higher speeds now envisaged the cooling problem was becoming acute. Thus, in aircraft destined to fly for more than a few minutes at speeds above Mach 2, it would not be possible to use aluminium for much of the structure, or else special cooling arrangements would have to be devised. Either way would lead to radical changes in construction. Steel appeared to be the most suitable material for the main structure; titanium was more likely to be used in engines and parts other than the main structure.

RADICAL DESIGN CHANGES LIKELY

Referring briefly to vertical take-off machines, pilotless guided vehicles, and nuclear-powered aircraft, Mr. Woodward-Nutt suggested that there might be drastic design changes within the next 10 or 20 years. Construction methods, therefore, must be planned for flexibility.

The lecturer then summed-up the pros and cons of integrated construction. While it had been argued that the method reduced costs owing to the saving in drawing, detail manufacture, and assembly time, the cost of plant both to produce the initial plates, forgings and extrusions and to process them had to be considered, remembering that the number of aircraft built to any one design was decreasing. Moreover, some allowance had to be made for the possibility of having to scrap large and costly parts as a result of machining errors at a late stage in the cycle.

Integrated construction should lead to a reduction in weight, owing to the fewer joints and ability to vary the skin thickness more uniformly. The resulting structure would be more rigid, and, with fewer bolt and rivet holes, should have a longer fatigue life. On the other hand, in a large forging it was difficult to ensure a satisfactory grain flow in the finished part. Owing to the thicker skins and fewer joints, it should be easier to provide the required surface smoothness in an integrated structure for high-speed aircraft. At still higher supersonic speeds, it might be more important to have a surface which radiated heat than one which was smooth, but that was still a long way off.

Integral construction had been claimed to speed-up production, due to the smaller number of parts, and offered possibilities of automatisation. However, errors at a late stage in a long machining cycle could cause serious delays. The time taken to make the dies, forgings, etc., had also to be considered, but on balance the lecturer felt that there probably was a time saving.

Finally, Mr. Woodward-Nutt raised a number of queries:—would integral construction permit the introduction of the modifications inevitable with rapid advances in design or operational requirements? And how would it affect maintenance and repair? Could the costly plant and tools be adapted for handling the components of a series of designs? Would rapid expansion of output be possible without expensive duplication of facilities? Would not reliance on the products of large presses, rolling mills, etc., mean a dangerous concentration of resources, and a risk of serious production delays if the key plant broke down? The issue, he suggested, was not altogether straightforward and simple.

Among the points raised in the discussion which followed Mr. Woodward-Nutt's lecture was the suggestion that, in order to make full use of the available volume of the high-performance aircraft, as well as to increase the structural efficiency, integral construction was inevitable. Admittedly, it was difficult to arrange for last-minute modifications and to cater for equipment changes. But Mr. Woodward-Nutt, in reply, said that the scheme for ordering 10 or 20 prototypes was intended largely to eliminate such modifications. Only one speaker appeared to favour retaining built-up construction methods, on two counts—the danger in time of war of having all technical resources concentrated in only one or two areas, and the difficulty of maintaining an adequate supply of skilled operators to work the complicated machines. This speaker recalled that during the Second World War production was expanded by making wide use of unskilled and semi-skilled labour in small factories dispersed throughout the country.

Several references were made to the savings which would result from the introduction of automatic electronic control of cutting tools, and one speaker pointed out that a new type of operator would have to be trained to use the computer-controlled machines.

Another suggestion for the better utilisation of resources was that fewer types of aircraft should be made in future, and that the smaller firms, which were at present attempting too much, should specialise in the design and construction of one main component, such as wings, or fuselages, instead of the aircraft as a whole, under sub-contract to a larger organisation. The design team could thus be kept together.

To be continued

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TELEVISION TECHNIQUES

Society's Annual Exhibition

The annual exhibition of the Television Society, held on January 6, 7 and 8 last, at University College, London, is a meeting ground for the discussion of problems and the inspection of new commercial equipment. This year there were 33 exhibitors.

Among the techniques which are making rapid progress is that of the printed circuit. Examples of this were shown by the Special Products Division of the Telegraph Condenser Company, Limited, North Acton, London, W.3. These circuits are made from a sheet of copper foil bonded on to a resin board; the wiring diagram is printed on the copper by a normal silk-screen process using an acid-resistant ink, and the unwanted parts removed by etching. Many printed components are now available including fixed and variable resistors, capacitors, transformers and chokes. Electrolytic and paper condensers are also now being made with special terminals for " plugging-in " to printed circuits so that the possibilities of dip soldering, in which all the components are soldered in one operation by dipping the assembly in a solder bath, can be extended.

J. S. Fielden (Devon), Limited, Branscombe, Seaton, Devon, were exhibiting a forward projection television set giving a screen picture of 4 ft. by 3 ft. A second model has adjustable focusing and will give pictures of any practical size over 20 in. by 15 in. The quality approaches that of a 16-mm. film. The set weighs 35 lb. and measures 12 in. by 9 in. by 18 in.

B.B.C. television programmes were relayed to the sets at the exhibition by Belling and Lee equipment. There was also a complete portable equipment exhibited by Marconi's Wireless Telegraph Company, Limited, Chelmsford, which had the camera mounted to scan the room and the signal passing to additional Belling and Lee apparatus for re-diffusion in the exhibition.

Colour television was represented by an exhibition of phosphorus shown by Derby and Company Limited, 11/12 St. Swithin's-Lane, London, E.C.4 and by a mask system which is now being developed by the Edison Swan Electric Company Limited, 155 Charing Cross-road, London, W.C.2.

ENGINEERS DEFINED

INTERNATIONAL AGREEMENT ON "PROFESSIONAL ENGINEER" AND "ENGINEERING TECHNICIAN"

Definitions of the "professional engineer" and the "engineering technician" are published in the January issue of *The Chartered Mechanical Engineer* (the journal of the Institution of Mechanical Engineers). They are reproduced below as a matter of interest to all who come within one or other of these categories.

The definition of a professional engineer lacks the directness and altruism of Tredgold's famous words.* The purpose of the engineer's work was the core of Tredgold's definition, but it is by-passed in the new definition. In its place we have a careful and elaborate formula based on the word "engineering." All that is needed now is a definition of engineering.

But the new definition is superior to Tredgold's in one important respect—it has been agreed by all the principal engineering institutions of the British Commonwealth, the United States and Western Europe, except the Institution of Engineers, Australia. So far as the British Commonwealth institutions are concerned, agreement to use these definitions was reached at their Conference held in London last summer. (A report on this conference is published in *The Chartered Mechanical Engineer*). It is, presumably, correct to infer that a corporate member of one of the three British chartered institutions is necessarily a "professional engineer," and equally that an "engineering technician" cannot be a corporate member of any of these institutions. But this point is not specifically made in the report of the Conference.

PROFESSIONAL ENGINEER

A professional engineer is competent by virtue of his fundamental education and training to apply the scientific method and outlook to the analysis and solution of engineering problems. He is able to assume personal responsibility for the development and application of engineering science and knowledge, notably in research, designing, construction, manufacture, superintending, managing and in the education of the engineer. His work is predominantly intellectual and varied, and not of a routine mental or physical character. It requires the exercise of original thought and judgment and the ability to supervise the technical and administrative work of others.

His education will have been such as to make him capable of closely and continuously following progress in his branch of engineering science by consulting newly-published work on a world-wide basis, assimilating such information and applying it independently. He is thus placed in a position to make contributions to the development of engineering science or its applications.

His education and training will have been such that he will have acquired a broad and general appreciation of the engineering sciences as well as a thorough insight into the special features of his own branch. In due time he will be able to give authoritative technical advice, and to assume responsibility for the direction of important tasks in his branch.

ENGINEERING TECHNICIAN

An engineering technician is one who can apply in a responsible manner proven techniques which are commonly understood by those who are expert in a branch of engineering or those techniques specially prescribed by professional engineers.

Under general professional engineering direction, or following established engineering techniques, he is capable of carrying out duties which may be found among the list of examples set out below.

In carrying out many of these duties, competent supervision of the work of skilled craftsmen will be necessary. The techniques employed demand acquired experience and knowledge of a particular branch of engineering, combined with the ability to work out the details of a task in the light of well-established practice.

An engineering technician requires an education and training sufficient to enable him to understand the reasons for and purposes of the operations for which he is responsible.

The following duties are typical of those carried out by engineering technicians:

Working on design and development of engineering plant and structures; erecting and commissioning of engineering equipment and structures; engineering drawing; estimating, inspecting and testing engineering construction and equipment; use of surveying instruments; operating, maintaining and repairing engineering machinery, plant and engineering services and locating defects therein; activities connected with research and development, testing of materials and components; and sales engineering, servicing equipment and advising consumers.

* "The art of directing the great sources of power in Nature for the use and convenience of man."

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PERSONAL

GENERAL SIR DARIL G. WATSON, G.C.B., C.B.E., M.C., secretary general of the British Transport Commission, is to retire in May. MAJOR GENERAL LLEWELYN WANSBROUGH-JONES, C.B., C.B.E., will join the British Transport Commission shortly and will succeed General Watson on his retirement.

The British Transport Commission have set up a Docks Management Board under the chairmanship of SIR ROBERT LETCH, general manager, British Transport Docks Division. The other members are MR. JOHN DONOVAN, C.B.E., chief labour officer, Docks Division, MR. R. P. BIDDLE, C.B.E., docks and marine manager, Southampton Docks, and MR. A. E. H. BROWN, chief docks manager, South Wales Docks.

DR. A. G. WHITE, M.Sc., F.R.I.C., F.Inst.P., M.I.Chem.E., a managing director of the Nobel Division of Imperial Chemical Industries Ltd., has retired after 40 years of service with the company and its predecessors.

MR. J. H. B. CHAPMAN, R.C.N.C., M.I.N.A., has been appointed principal deputy director in the Department of the Director of Naval Construction, Admiralty, Foxhill, Bath, in succession to MR. H. S. PENGELLY, C.B., R.C.N.C., M.I.N.A., who retired on November 30, 1954.

SIR SUMMERS HUNTER has expressed a wish to relinquish the managing directorships of the operating companies in the Richardsons Westgarth Group on January 31, but will continue to be a member of their boards. The following become the managing directors of the respective companies from February 1: MR. HARRY HUNTER, of the North Eastern Marine Engineering Co. Ltd., MR. T. P. EVERETT, of Richardsons Westgarth (Hartlepool) Ltd., and MR. W. R. JONES, of George Clark (Sunderland) Ltd.

MR. JOSEPH WALTON is to retire from the joint managing directorship of Thos. W. Ward Ltd., Albion Works, Sheffield, on January 31, but will remain available in a consultative capacity and will retain his position as chairman and managing director of the Darlington Railway Plant and Foundry Co. Ltd., Darlington.

MR. L. M. BROADWAY has been appointed chairman of John B. Pillin Ltd., a member of the Wakefield group of companies, in succession to MR. ALONZO LIMB, who has resigned on account of ill-health. MR. C. E. R. MILLIDGE and MR. J. J. BROOKMAN have been elected directors of the company.

DR. A. W. SKEMPTON, Reader in Soil Mechanics at the Imperial College of Science and Technology South Kensington, London, S.W.7, has been appointed to the London University Chair of Soil Mechanics, tenable at that College.

MR. C. F. J. FRANCIS-CARTER, O.B.E., has been appointed managing director of the Aluminium Wire and Cable Co. Ltd., Port Tennant, Swansea. He has been general manager of the company since its inception early in 1947.

MR. R. F. EARLEY, B.Sc., A.M.I.C.E., A.M.I.Mun.E., F.G.S., civil-engineering consultant, informs us that he now has a London office at 4 Curzon-place, W.1, (Telephone: GROsvenor 5111) and will collaborate, in future, as an associated consultant with Bolton, Hennessey & Partners of the same address.

MR. E. CASSLETON ELLIOTT, F.S.A.A., chairman of Kerry's (Great Britain) Ltd., Warton Road, Stratford, London, E.15, was created a C.B.E., in the New Year Honours.

DR. T. L. IBBS, lecturer in physics and admissions tutor for the Faculty of Science, University of Birmingham, has been appointed to a personal chair in the Department of Physics of the University. He will assume responsibility for the administration of the department, thus enabling its head, PROFESSOR P. B. MOON, to concentrate upon nuclear research.

MR. H. P. PENTELOW has retired after 51 years of service with Lancashire Dynamo & Crypto Ltd., Trafford Park, Manchester, 17.

MR. R. T. ROLFE, O.B.E., F.R.I.C., F.I.M., has retired from the position of chief metallurgist to W. H. Allen, Sons & Co. Ltd., Queen's Engineering Works, Bedford, and is succeeded by MR. J. R. BRYANT, B.Sc., hitherto deputy chief metallurgist. Mr. Rolfe remains associated with the company in a consultative capacity.

MR. WALLACE REDPATH, lecturer in the Department of Mechanical Engineering, Paisley Technical College, Renfrewshire, has sailed for Burma to take up an appointment as senior lecturer in the Faculty of Mechanical Engineering of the University Rangoon, under the Colombo Plan's Technical Co-operation Scheme.

MR. A. J. HEYWORTH, D.F.C., has been appointed chief test pilot to Rolls-Royce Ltd., Derby. MR. H. C. ROGERS is to be his assistant.

MR. F. G. PENTECOST, who last year celebrated his 50th year of service with A. Boake, Roberts & Co. (Holding) Ltd., Carpenters Road, Stratford, London, E.15, has retired from the office of managing director. He will continue as chairman of the company and its main subsidiary company, A. Boake, Roberts & Co. Ltd. MR. BERTRAM WHITE, B.Sc.(Lond.), F.R.I.C., has been appointed managing director of both companies. MR. T. A. MASON, M.A., B.Sc., has joined the company as general works manager of the Stratford, Rainham and Letchworth factories.

MR. R. H. BANNISTER, for the last 10 years manager, Scotland and Ireland, for the English Electric Co. Ltd., Stafford, has been appointed manager of the home branch organisation, and is now stationed at the Stafford Works. MR. P. MCNEE, formerly manager of the firm's Edinburgh office, is appointed manager, Scottish territories. MR. W. M. TODD, now technical representative at the company's Cardiff office is appointed manager, Edinburgh office, under Mr. McNee, and will commence his new duties on March 14.

MR. G. H. BARNARD, M.Inst.F., formerly area engineer to the National Industrial Fuel Efficiency Service in Wales, has been transferred to the head office in London, to undertake work that is expected to result from the report of the Beaver Committee on Air Pollution. Mr. Barnard's successor as area engineer in Wales has been taken up by MR. C. A. J. PLUMMER, M.Sc., A.R.I.C. MR. H. H. GRATTIDGE, M.I.H.V.E., has been appointed area engineer for Scotland, in succession to MR. J. EDWARD, M.B.E., to whom he was deputy. The post of deputy engineer for Scotland is now filled by MR. W. SHORT, B.Sc.

MR. C. B. CLAPHAM, B.Sc. (Eng.), A.M.I.Mech.E., assistant to the works manager (buses and coaches), London Transport Executive, has now been attached to the office of the chief mechanical engineer (road services) with the title of assistant to the chief mechanical engineer (road services). MR. A. G. HIGGINS, A.M.I.Mech.E., at present chief development assistant (buses and coaches) has been appointed principal executive assistant.

MR. J. A. GRACE, hitherto contracts manager, de Havilland Aircraft Co. Ltd., is now taking up an appointment as commercial manager of Folland Aircraft Ltd., Hamble, Southampton.

MR. N. G. THOMAS, manager, machine-tool division, Dunlop Rubber Co. Ltd., Fort Dunlop, Birmingham, has retired.

MR. A. E. BELL has been appointed sales manager (engineering) of the Distington Engineering Co. Ltd., Workington, Cumberland.

MR. L. F. PARSONS has been appointed a technical sales representative of Jenolite Ltd., 13-17 Rathbone-street, London, W.1, and is based in London.

MR. W. DAWSON, 14 Airedale-street, Bradford, 2 (Telephone: Bradford 37996) has been appointed permanent northern representative of the Accurate Recording Instrument Co., Morden, Surrey.

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COMMERCIAL

BURTON, GRIFFITHS & CO. LTD., Mackadown-lane, Kitts-green, Birmingham, 33, have decided to centralise all stocks of small tools and engineering equipment at the headquarters of their small-tools division, Montgomery-street, Birmingham, 11, and to cease the holding of stocks at provincial branches. The new policy does not affect the firm's London branch which will operate as hitherto.

SMITHS INDUSTRIAL INSTRUMENTS LTD., Chronos

Works, North Circular-road, London, N.W.2, announce that their Scottish depot has been moved from Bothwell-street, Glasgow, to 123-145 North-street, Glasgow, C.3. (Telephone: Glasgow Central 3972-8.)

MARTIN, BLACK & Co., (WIRE ROPES) LTD., Speedwell Works, Coatbridge, near Glasgow, have opened a stores depot at 640, Woodborough Road, Mapperley, Nottingham. (Telephone: Nottingham 47293.)

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PRIVATE TEST TRACK FOR MOTOR VEHICLES

Rover Company's Venture

The Rover Company, Limited, Solihull, Birmingham, give every one of their vehicles an individual road test before passing it for dispatch. To be of maximum value all the tests should be strictly comparable, and if public highways are used it is impossible to guarantee that the same stretch of road will be available each time, or that there will be the necessary freedom from other traffic to enable observations of noise in the bodies and mechanical parts of vehicles to be carried out. The high traffic density in the Birmingham area accentuates these problems.

The company have therefore built a special test track on their own land adjoining the Solihull works, and the entire output of Rover cars and Landrovers will in future be tested on this track under ideal conditions. The track, which is claimed to be the only one of its kind in Great Britain, has a circuit of 2·285 miles, and has a width of 20 ft. for the whole distance. It is built in rural surroundings, on a flexible base to suit the sub-soil. Traffic circulation is anti-clockwise, to enable the left-hand rule of the road to be observed more easily. Under this arrangement there are six left-hand bends and four right-hand bends. Special sections of the track are reserved for testing brakes and gearboxes, and there are several lay-bys where adjustments can be carried out well clear of moving vehicles.

There are no special surfaces or other methods of providing difficult conditions, as the track is not intended to offer facilities which already exist at the Motor Industry Research Association's track at Lindley, near Nuneaton. It is designed for the routine testing of the whole of the Rover Company's production of vehicles under ordinary road conditions, and will enable observations to be carried out on brake performance, mechanical, body and tyre noise, suspension and fuel consumption. It is possible, however, that special test sections will be built in the future should it be considered necessary to provide these facilities for routine testing of production vehicles.

The Rover test track provides facilities for testing the whole of the Company's output of cars and Landrovers under road conditions.

PLASTICITY IN DESIGN

DETERMINING THE POST-YIELD LOAD CAPACITY OF MATERIALS

The theory of plasticity is concerned with the analysis of stresses and strains in the plastic range of ductile materials, especially metals. Applied to the design of machines and structures, it represents a necessary extension of the theory of elasticity in that it furnishes more realistic estimates of load-carrying capacities. Applied to forming processes such as machining, pressing, extruding, rolling, and drawing, it provides the basis for improved control through better understanding of the role of the relevant mechanical variables.

This paragraph formed the opening of the James Clayton Lecture* given at the Institution of Mechanical Engineers last Friday, January 14, by Dr. William Prager, Mem.A.S.M.E.† Following a short historical review, Dr. Prager described the various forms of dynamic and kinematic models that had been devised to assist the investigation of the physical properties of plastic solids. Then came a discussion of the fundamental theorems of limit analysis, and definitions were given of "shakedown" analysis and limit design; problems involving large deformations were discussed with special reference to the metal-forming processes, and applications of the theory of plasticity to impact testing and blast damage were reviewed. Throughout the lecture reference was made continuously to published work from many sources, and the paper concluded with an extensive bibliography of the work of nearly 100 investigators and about 300 of their publications.

MATHEMATICAL MODELS

In describing the various forms of mathematical models which have been devised to give physical representation of the mechanical properties of plastic solids, Dr. Prager pointed out that it could not be expected that a single model could be constructed to incorporate all the possible factors simultaneously. Even if such a model were constructed it would be far too complex to serve as a basis for investigating technical problems. Simple models had to be used representing only those elements essential to any considered problem.

The first and simplest group of models employed helical springs and blocks subjected to solid friction when drawn over the plane surfaces supporting them, plastic strain being simulated by slip under solid friction. While these two basic models could be used in combination for many purposes, including the demonstration of work-hardening phenomena, it did not seem possible that models employing solid friction could ever be made to represent plastic flow under combined stresses.

More comprehensive systems were obtained if, instead of dynamic models, kinematic models that represented stresses by displacements were used. The simplest form, representing a rigid perfectly-plastic solid under uniaxial stress, consisted of a slotted plate sliding freely between frictionless guides and a pin moving without friction in the slot of the plate; the movement of the pin was imparted to the plate only when the pin engaged with one or other of the ends of the slot. The plate, guides and pin each carried an index line which were initially aligned when representing conditions of zero stress and strain. The displacement of the pin with respect to the plate represented the stress, and that of the plate with respect to the guides represented the strain; the total free displacement of the pin in the slot was then a measure of twice the yield stress.

This same device was readily adapted to the rigid work-hardening solid or the elastic perfectly-plastic solid; its adaptation to elastic work-hardening solids, while possible, was less straightforward and was not discussed further in the lecture.

As an example of the treatment of complex stress—due to combined direct force and bending—and as an extension of the simple kinematic model just described, the case of a sandwich-type beam was considered. The beam consisted of two flanges of unit cross-sectional area joined by a layer which carried shear but no direct stresses, and the flanges were taken to be sufficiently thin that variations of stress and strain over the thickness of the flange could be neglected.

For this example the mathematical model was adapted from that just described as follows. A square rigid frame was mounted so that it could undergo any translation in its plane; a perfectly smooth pin, free to move inside the frame, imparted a motion to the frame only when it pushed against the side or engaged with the corner of the frame. Initially, both frame and pin were centred at the origin of the strain ordinates; as the frame was displaced by the moving pin, the vector from the origin to the frame centre had the components of the strain in the two flanges, and the vector from the frame centre to the pin centre had components of the stresses in the flanges. By suitably choosing the dimensions of the frame, consideration of the geometry of the relative positions of the original ordinates, of the pin, and of the displaced and possibly orientated frame, made it possible to deduce easily the variations in the stresses and strains for changing conditions of the beams. Such kinematical models revealed the mechanical complexity of even such a simple plastic continuum as that of the sandwich beam considered. For example, the dependence of the final plastic deformation on the history of loading corresponded to the dependence of the slip between the frame and pin on the path of the pin; since no slip took place as long as the pin remained engaged with the corner of the frame, there was a limited path of independence of the final plastic deformation for certain modes of loading.

A further modification of the simple kinematic model was to change the square frame to a circular frame when it assumed a form convenient for checking proposed stress-strain relations for combined tension and torsion of thin-walled cylinders. By then allowing this circular frame to distort as it was engaged by the pin it was

* "The Theory of Plasticity: A Survey of Recent Achievement."

† Professor of Applied Mechanics, Brown University, Providence, Rhode Island, New York, U.S.A.

possible to introduce the effect of work hardening into the problem. By further changes in the shape and form of the frame so was it possible to devise models which would represent more complex conditions of loading in materials which possessed a variety of limiting physical properties.

LIMIT ANALYSIS

From the discussion of the more theoretical aspects of the problems of plasticity, Dr. Prager turned to more practical problems, his first example being concerned with the ultimate load-carrying capacity of beams. Considering a beam with built-in ends and carrying a point load at a point other than at the centre, it was shown why a plastic hinge could be thought to develop first at one support, then at the other, and then, if appreciable deflections could occur, at the point of loading. Thus it was shown how, in principle, the load-carrying capacity of indeterminate structures could be determined by analysing a sequence of elastic structures of decreasing degrees of redundancy.

Though in simple cases it was possible to presume the arrangement of the hinges with accuracy, it was not always so. In such cases, two lines of approach were available for considering any hypothetical arrangement. By considering the maximum shear generated by the formation of the hinges, a load intensity could be found that could not be larger than the critical intensity; alternatively, equating the energy dissipated at the hinges to the work done enabled a load intensity to be determined that could not be smaller than the critical. By adjusting the hinges until these two values from above and below approached sufficiently close, the location of the hinges could be determined to any degree of accuracy.

This technique of bounding or limiting the critical load intensity was by no means restricted to structures composed of beams and frames, and the arguments that had been proposed for the example of the encastré beams were extended in the form of two fundamental theorems which could be applied to problems encountered in mechanical engineering. The two theorems could be stated as follows :

(1) The given loads are below the critical intensity if a stress field can be found that is in equilibrium with these loads and nowhere reaches the yield limit.
(2) The given loads are above the critical intensity if a velocity field can be found for which the rate of work of these loads exceeds the rate of internal energy dissipation.

As an example of the use of these theorems the lecturer quoted the case of bending a deeply notched bar (which was wide enough to bend in plane strain). The yield condition was one of yielding under constant maximum stress. Below the apex of the notch the beam could be divided into two zones of equal depth (this implied that yield occurred when the compressive and tensile stresses were of equal magnitude), one zone being under a uniform compressive stress the other under uniform tensile stress; these stresses were numerically equal to twice the yield in simple shear. The stress field was thus discontinuous at the line separating the two zones. Arguments based on the first of the theorems stated above enabled the lower limit for the critical bending moment to be found.

The second theorem was then used to fix the upper limit of the moment by setting up a succession of discontinuous velocity fields of increasing complexity and equating the work that would be done to the internal energy that would be dissipated. By applying the theory of the slip-line field, zones of energy dissipation could be determined which were successively more realistic and approached more nearly to the lower limit previously found. Qualitative support for these arguments was forthcoming in a photo-micrograph of the etched cross-section of such a notched beam of mild steel exhibiting regions of plastic deformation of the form deduced by use of the theorems. The lecturer then gave three examples to illustrate how far the theorems and associated approaches had been used to resolve three-dimensional punch-indentation problems.

There was, however, a serious restriction on the usefulness of limit analysis which resulted from neglect of the effect of the plastic deformations on the equilibrium conditions. Tentative methods likely to overcome this restriction were illustrated by describing the preliminary examination of a thin circular plate loaded by a central punch so that the plate was caused to deform into a series of conical shells which were amenable to treatment. The full elaboration of these methods would develop a method of limit design which would permit the economical allocation of yield strength to the members of a structure in such a manner that applied loads would not exceed its load-carrying capacity.

LARGE PLASTIC DEFORMATIONS

On turning to forming processes such as rolling and extruding, Dr. Prager pointed out that assumptions concerning infinitesimal deformations had to be abandoned. Even in the theory of elasticity, finite deformations posed a considerable mathematical problem and it followed that theories for finite elastic/plastic deformations would be even less tractable and therefore of little use in dealing with forming processes.

Like the Newtonian viscous liquid, the rigid perfectly plastic solid was characterised by a stress-strain law that linked the stress to velocity strain without containing the strain. Most work on large plastic deformations was based on this type of material and, to take advantage of the theory of the slip-line field (which was as yet still limited to two-dimensional analysis) the work was almost exclusively concerned with problems of plane plastic flow. Recent work could be distinguished from the earlier by the better understanding of the interplay between static- and kinematic-boundary conditions. In the older literature too much attention had been given to the construction of statically determinate stress fields from the appropriate boundary conditions for the stress.

A typical problem to be treated was that of the extrusion of sheet metal through a rough die. While it was quite possible to define the velocity field throughout the considered mass, the stress pattern could only be determined within a limited zone originating at the periphery of the die. The extrusion pressure found from this incomplete stress field could be shown to be identical with that obtained from the associated velocity field by means of the second of the theorems already enunciated. This extrusion pressure was therefore the upper limit to the actual extrusion pressure. It was to be accepted only as the true pressure, however, if the stress field could be extended to the boundaries of flow mass without the mapping of stress exceeding the yield limit. Similar problems, also elaborated in the lecture, included the stresses in a semi-infinite plastic mass being indented by a lubricated rigid wedge and the converse of a plastic wedge being squashed by a rigid plate.

It was noted by the lecturer that, so long as certain general assumptions (e.g., plane stress or plane strain, perfectly smooth or completely rough surfaces) were accepted any problem could be resolved rigourously within the framework of, say, the theory of perfectly plastic solids without the introduction of any *ad hoc* assumptions. For many forming processes it was still necessary to use semi-empirical theories as, for example, for the cold rolling of strip. If the width of strip was large, however, the assumption of plane flow was justified and the theory of slip-line field could be applied, though not with complete success.

DYNAMIC PROBLEMS

When the theory of plasticity was applied to problems of impact testing or blast damage, the plastic flow could no longer be regarded as slow, and inertia forces had to be included in the analysis. Most of this work was concerned with elastic work-hardening solids; the kinetic effects of longitudinal motion only were considered, those of the associated lateral expansions and contractions being neglected. In considering loading by blast, the elementary problem to be analysed was that of a simply-supported beam subjected to a uniform transient load that rose suddenly from zero to some peak which was maintained for some interval of time before again falling to zero (and possibly to a negative loading with respect to the first effect). Assuming that the critical moment was exceeded. a hinge was formed at mid span and each part of the beam rotated as a rigid body about the end support. The angular acceleration, which could be assumed constant so long as deflections were small compared to the span, was to be determined from the dynamic equilibrium of the part of the beam under the combined action of the distributed load and of the moment acting at the beam centre. If the maximum moment should reach a sufficiently high figure it was possible that additional hinges would be formed, but (within the limits of the assumptions) it was possible to estimate the position and angular velocity at the instant of load removal. After the load was removed, the fully-plastic bending moment acting at the centre produced an angular deceleration from which the final position of the beam could be found.

Dr. Prager concluded his lecture by drawing attention to the large number of studies which had been made of particular problems by adapting formulae for elastic stability to the experimental results in the plastic range by the substitution of functions of stress intensity for the elastic constants. This led to the use of physically untenable total stress-strain relations instead of incremental relations. The partial success of these methods had obscured basic thinking on the subject, but the advent of the new concepts would now enable the theory of plastic stability to be developed from first principles. Recent developments justified the hope that the next decade would see the solution of a host of practically important problems that had hitherto proved intractable.

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ELECTRICAL ENERGY

"Unipede" Congress in London

Several hundred representatives of electricity-supply undertakings in the principal European countries are due to visit British hydro-electric plants during the coming autumn. The tours will follow the tenth congress of the International Union of Producers and Distributors of Electricity ("Unipede"), which is being held under the presidency of Lord Citrine, K.B.E., chairman of the British Electricity Authority. It will be the first occasion on which a congress organised under the auspices of the Union has taken place in this country.

Business and technical sessions of the congress will be held at Church House, Westminster, London, S.W.1, from Monday, September 19, to Friday, September 23. There will be two study tours to Scotland, one of which will visit hydro-electric schemes at Tummel Valley, Glen Affric, Glen Garry and Glen Moriston. The second tour will include the Loch Sloy scheme and Portobello Power Station in its itinerary.

Unipede, which has its permanent secretariat in Paris, was founded in 1925 and is an association of those organisations which, in each country, chiefly represent the interests of that country's producers and distributors of electricity. The Union is principally concerned with general economic and engineering problems relating to electricity supply, with international transfers of electrical energy, and with the compilation of statistics. Active members of the Union include representatives of the electricity-supply industry in Europe.

Further information may be obtained from the public relations officer, British Electricity Authority, Winsley-street, London, W.1.

Obituary

MR. H. CECIL BOOTH, M.I.C.E.

Inventor of the Vacuum Cleaner

It is with much regret that we record the death, on January 14, of Mr. H. C. Booth, F.C.G.I., M.I.C.E., the inventor of the vacuum cleaner and a consulting engineer of note and eminence in a number of widely differing fields. He was 83 years of age.

Hubert Cecil Booth was born on July 4, 1871, and commenced his engineering training by taking the civil and mechanical engineering course at the City and Guilds Technical College, South Kensington, between 1889 and 1892, under the late Professor W. C. Unwin, being awarded the diploma of A.C.G.I. On the completion of this course he entered the drawing office of Maudslay, Sons and Field, Lambeth, at that time under the control of the late Mr. Charles Sells. There he made the acquaintance of Lieut. W. B. Basset, R.N. (retd.), who had acquired the British rights for the construction of Graydon's " Big Wheels," one of which was to be made for an exhibition at Earl's Court; it was 270 ft. in diameter, and designed to carry 1,600 people. After working on this design for some time, and influencing it in no little measure, Booth was appointed by Basset to design the Great Wheels for Blackpool (200 ft. diameter), Paris (300 ft.) and Vienna (200 ft.), and to supervise their construction and erection. He also went to Belgium for Basset, constructing and eventually managing for him a structural steel works at Houdeng.

Meanwhile, in 1901, he had invented and patented a machine for extracting dust from carpets, etc., which he named the " vacuum cleaner." It was based on the simple experiment of sucking, with his mouth, through a handkerchief held in close contact with a dusty plush-covered settee, an experiment which proved to be much more effective than he had expected. Realising the value of the invention, Booth took out world patents and founded, with Colonel C. F. Hitchins, the Vacuum Cleaner Company, afterwards called the British Vacuum Cleaner and Engineering Company, of which he became chairman and managing director; thus began the vacuum-cleaning industry throughout the world, industrial and domestic, which has now attained to such remarkable dimensions. Booth continued to direct the affairs of this company until 1952, when he retired.

Important as the invention of the vacuum cleaner proved to be, it was not the main interest in Booth's life at the outset; in 1900, he had set up in practice as a consulting engineer in partnership with Mr. C. F. Hitchins. Afterwards, he was joined by Mr. J. S. Wilson, M.I.C.E., and the late Mr. C. W. Pettit, M.I.Mech.E., and various others in the following quarter of a century. The main interest of the consulting firm was not vacuum cleaners, but bridges and structural engineering, and in this field they soon established a reputation. Booth was still only 31 when, at the joint request of Sir John Wolfe Barry and of the contractors, Arrol's Bridge and Roof Company, he assumed entire charge of the erection of the Connel Ferry railway bridge—a cantilever structure with a single span of 736 ft.—and of the Creagan bridge over Loch Creran, both in Argyllshire, and completed them with such expedition as to obtain for the contractors a bonus of £10,000. In succeeding years he designed many bridges for the Great Western, Southern and other railway companies, and a considerable number for countries overseas, among the latter being numerous suspension bridges in Burma and elsewhere. He retired from consulting practice in 1940, but continued his connection with the British Vacuum Cleaner Company for a further 12 years, as mentioned above.

Booth was a Member of the Institution of Civil Engineers, to which he was admitted initially as a Student, becoming an Associate Member in 1897 and Member in 1910. The City and Guilds Institute awarded him the diploma of Fellow in 1904; and in 1920 he was President of the Old Centralians. He was also a founder member of the Maudslay Society and was its President in 1947–48. In addition to his connection with the British Vacuum Cleaner Company, for whom he designed a number of special plants for the extraction of explosive dusts from munition factories and for the removal of flue dust from power-station boilers, he was a director of Roadless Traction, Limited, of Hounslow, makers of tracked vehicles for agricultural and other purposes.

Mr. H. Cecil Booth

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MR. W. A. YOUNG

We also regret to record the death, on January 13, of Mr. William Arthur Young, who was associated for more than half a century with our contemporary, *The Ironmonger*, of which he was editor from 1925 to 1934. Mr. Young, who was in his 88th year, having been born on July 26, 1867, was apprenticed to a firm of ironmongers in Cambridge who also operated a foundry, casting both iron and non-ferrous metals, and who could trace the history of their business back to 1688. He grew up, therefore, in an environment which encouraged the keen interest in the history of engineering and in metal craftsmanship which he displayed to the end of his long life. He joined the staff of *The Ironmonger* in 1900, was appointed assistant editor in 1913, and succeeded to the editorial chair in 1925. After his retirement in 1934 he continued to contribute to the journal until a few months ago.

Young was one of the earliest members of the Newcomen Society for the Study of the History of Engineering and Technology and was the author of a number of papers in its *Transactions* in addition to his Presidential address, delivered in November, 1939, on " Thomas Newcomen, Ironmonger "; in this he argued with reason that the construction of the first reciprocating steam engine by Newcomen in 1711-12 was not necessarily beyond the capacity of a country ironmonger of that period, whose business—like that of the firm with whom Young himself had been apprenticed—was more that of a general engineer than of a mere retailer. Perhaps his most interesting paper, however, was his " Notes on a Bygone Japanese Craft," delivered in 1937 and dealing with the technique of Japanese inlaid *tsuba*, or sword mounts. This was a subject on which he was a specialist, and the owner of one of the finest private collections in the country of this type of sword furniture. He was also the author of a well-known work, *The Silver and Sheffield Plate Collector*; and, almost incidentally, an authority on Kipling. To all of these studies he brought an inquiring mind and a penetrating judgment of controversial evidence, greatly aided by a long memory of the details of craftsmanship as he had seen it in operation since his boyhood in small workshops all over the British Isles, before the stock-in-trade of the country ironmonger came to consist so largely, as it does to-day, of machine-made factory products.

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We regret also to record the deaths of:

SIR ERNEST ALBERT SEYMOUR BELL, C.I.E., M.I.C.E., F.C.H., at his home in Roehampton-lane, London, S.W.15, on January 8, in his 88th year. A former member of the Railway Board, Government of India, he retired in 1926 and, until recently, was chairman of the Barsi Light Railway. Sir Ernest received his engineering training at the Royal Indian Engineering College, Coopers Hill, near Egham, Surrey.

JAMES M'FARQUHAR PETTERS, M.I.C.E., M.I. Mech.E., at his home in Cheam, Surrey, on January 7, at the age of 83. Appointed assistant engineer, irrigation, Government of India Public Works Department, in 1892, Mr. Petters served as executive engineer, buildings and roads, Burma, from 1895 until 1914 and superintendent and sanitary engineer, Government of Burma Public Works Department, from 1914 until 1919. He was for many years a director of Taylor & Petters Ltd., makers of mica and other insulators, City-road, London, N.1.

PROFESSOR LIONEL S. MARKS, on January 6, at the age of 83. He was Gordon Mackay Professor Emeritus of Mechanical Engineering at Harvard University, Cambridge, Massachusetts, U.S.A., and the author of *The Mechanical Engineer's Handbook*. He was born in 1871 at Birmingham, England, and joined the faculty of Harvard in 1894, retiring in 1940.

BRIGADIER EDWIN JOHN JAMES BRITTON, C.B.E., D.S.O., suddenly when out walking in London, on January 12, at the age of 74. After receiving his education at the Royal College of Science and the University of Dublin, Britton obtained a commission in the Royal Army Ordnance Corps in 1900 and eventually rose to the rank of Chief Ordnance Mechanical Engineer, Aldershot Command, and retired in 1937 as Principal Ordnance Mechanical Engineer, War Office. He served again throughout the war of 1939-45 and finally retired in December, 1945.

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CONTRACTS

Air Compressors. A contract has been obtained by the GENERAL ELECTRIC CO. LTD., Magnet House, Kingsway, London, W.C.2, for a large air-compressor plant. The contract has been let by the Ministry of Works and the equipment is for new Government research and testing facilities. It comprises two sets of turbine and motor-driven air compressors with ancillary equipment. The installation will exceed 80,000 h.p., with the compressors arranged for operation in series or in parallel. The compressors may also be operated as exhausters.

Prestressed Concrete. The steel for the new prestressed-concrete bridge at Kallang Basin, Singapore, has been ordered from MCCALLS MACALLOY LTD., Templeborough, Sheffield. The bridge, to be one of the longest prestressed-concrete bridges in Asia, will comprise 25 spans of 80 ft. having a total width of 65 ft.; 500 tons of " Macalloy " steel is required. The same company are also to supply the prestressing steel for the Mahi Bridge, near Baroda, to be built by the Hindustan Construction Co. of Bombay; this bridge will have 16 spans each of 110 ft.

Marine Reverse-Reduction Gears. CANADIAN-VICKERS LTD., Montreal, are to build, this year, a new 8,000-h.p. hydrographic survey ship for the Canadian Government. The vessel will be equipped with two British-built Hindmarch/MWD twin-engine oil-operated reverse-reduction gears coupled to four FAIRBANKS-MORSE engines, each engine transmitting 2,000 b.h.p. at an input shaft speed of 750 r.p.m. The propeller speed will be 200 r.p.m. Canadian-Vickers Ltd. are the Canadian representatives of MODERN WHEEL DRIVE LTD., Lindo Lodge, Stanley-avenue, Chesham, Buckinghamshire, designers and manufacturers of Hindmarsh/MWD multi-engine oil-operated reverse-reduction main propulsion transmissions.

The Engineering Outlook—2

MANPOWER IN ENGINEERING

FULL EMPLOYMENT AND MECHANISATION

It is often said that generals are always preparing to win the last war. This is an attitude of mind, however, to which everyone is prone. It is becoming increasingly clear, for instance, that it may yet do serious damage to the engineering industry. Never before has it been so apparent that the industry must prepare for a series of important technical and economic changes in the future: yet signs are not lacking that both sides of the industry are peering somewhat anxiously into the past.

Ahead, there is the prospect of a continued long-term key role for the engineering industry in the van of the export drive, a growing need for labour to adapt itself to rapid technical change involving a much higher value of capital per worker leading on eventually to the automatic factory in greater or less degree—a line of development which if successfully achieved can mean significantly higher real earnings for workers. Behind, lies the recollection of the depressed days of the 1930's, the traditional if narrowing gap between craftsman and unskilled worker and the precedent of local custom.

In between is the present which must bring together the good prospect of the future with all that is best from the past. It is a formidable task, for the present has its own problems and tensions in human relations which are only too evident, for 1954 closed with a major wage demand from the Confederation of Shipbuilding and Engineering Unions. This wage demand, and the circumstances in which it has been made are, in fact, the conditions of the present which will mould the shape of the future of labour relations in the industry. To these conditions, therefore, we must first turn.

TABLE I.—*Great Britain: Employment in the Metal Manufacturing and Engineering Industries. (Thousands)*

—	Sept., 1952	Sept., 1953	Sept., 1954
Metal Manufacture	560·5	550·7	558·8
Blast furnaces	22·7	21·8	21·8
Iron and steel melting, rolling, etc.	217·9	222·4	221·1
Iron foundries	127·8	124·8	125·8
Tin-plate manufacture	18·8	13·9	14·4
Steel sheet manufacture	19·5	19·6	20·2
Iron and steel tubes (incl. melting and rolling in integrated works)	45·9	44·0	44·8
Non-ferrous metals, smelting, rolling, etc.	107·9	104·2	110·7
Engineering, Shipbuilding and Electrical Goods	1,905·4	1,917·5	1,989·1
Shipbuilding and ship repairing	208·1	208·5	204·5
Marine engineering	75·6	76·1	75·4
Agricultural machinery (excl. tractors)	41·7	38·9	41·7
Boilers and boiler-house plant	30·0	30·0	31·2
Machine tools	100·9	101·8	103·3
Stationary engines	25·1	26·1	27·0
Textile machinery and accessories	73·4	66·5	67·5
Ordnance and small arms	59·5	62·6	66·7
Constructional engineering	79·0	84·9	85·6
Other non-electrical engineering	616·2	618·1	636·5
Electrical machinery	175·6	174·1	180·2
Electric wires and cables	62·8	58·0	60·3
Telegraph and telephone apparatus	55·2	53·9	53·3
Wireless apparatus (excl. valves) and gramophones	98·1	112·1	126·7
Wireless valves and electric lamps	40·6	41·0	45·7
Batteries and accumulators	19·4	19·9	21·1
Other electrical goods	144·2	145·0	162·4
Vehicles	1,076·2	1,109·1	1,155·4
Manufacture of motor vehicles and bicycles	298·8	298·1	316·3
Motor repairers and garages	260·6	269·8	270·7
Manufacture and repair of aircraft	201·1	221·6	235·4
Manufacture of parts and accessories for motor vehicles and aircraft	139·0	147·4	159·8
Railway locomotive shops	61·7	57·5	57·3
Manufacture and repair of railway carriages and wagons and trams	82·1	81·0	81·3
Carts, perambulators, etc.	7·6	8·1	8·6
Other locomotive manufacture	25·3	25·6	26·0
Metal Goods not elsewhere specified	492·0	486·2	509·6
Tools and cutlery	48·5	44·9	48·1
Bolts, nuts, screws, rivets, nails, etc.	42·0	39·3	40·0
Iron and steel forgings, not elsewhere specified	39·7	38·6	39·0
Wire and wire manufacture	38·8	37·9	39·7
Hollow-ware	56·4	60·8	62·3
Brass manufacture	47·7	45·7	49·7
Metal industries not elsewhere specified	218·9	219·0	230·8
Precision Instruments, Jewellery, etc.	130·4	135·6	142·2
Scientific, surgical and photographic instruments, etc.	80·5	85·7	88·4
Manufacture and repair of watches and clocks	15·5	16·5	18·5
Jewellery, plate and refining of precious metals	26·0	24·9	26·3
Musical instruments	8·4	8·5	9·0

Whichever way it is measured, the engineering industry had a prosperous 1954 and can look forward with confidence to 1955. Taking the yardstick of employment, it is apparent from the figures in Table I (even though they cover only the first three-quarters of the year) that the year just ended saw a continued upward trend in employment. Numbers employed in engineering, shipbuilding and electrical goods increased by 4 per cent. over the first three-quarters of the year, compared with ½ per cent. in the same period of 1953. The corresponding figures in vehicle manufacture of all kinds were 4 and 3 per cent.; in precision instruments, 4 and 4 per cent. In other metal goods (the fourth main category in Table I) the change was even more striking. Employment dropped from September, 1952, to September, 1953, by 1 per cent., followed by a recovery of nearly 5 per cent. in 1954.

Over the year to September, 1954, the only major engineering categories to record a decline in employment were shipbuilding, marine engineering, telegraph apparatus and railway locomotive workshops. Only in the case of shipbuilding was the fall more than fractional, amounting to 2 per cent. Not all groups, however, made good their individual losses in 1953. Thus, compared with two years ago, fewer people were employed in the manufacture of textile machinery, electric wires and cables, telegraph apparatus, cutlery, screws and rivets, miscellaneous iron and steel forgings and railway wagons, and in the repair of railway locomotives.

INCREASED DEMANDS FOR CONSUMER GOODS

Despite these pockets of more sluggish recovery in late 1953 and early 1954, the general picture is one of prosperity. The industry added about 4 per cent. to its manpower, as stated above, and its increase in output has kept pace with that for industry in general. The industrial boom which developed last year owed a great deal, in fact, to the metal goods and heavy engineering industry before the Budget last April introduced the new investment allowance. As the year went on the heavier end of the industry held its gains, but the impetus which the engineering industry has continued to give to industrial production throughout 1954 owed more and more in the later months to the lighter section of the industry where towards the end of the year, a relaxation of hire-purchase controls stimulated demand for a wide range of durable consumer goods. Throughout the year, however, the motor vehicle industry has maintained a continued record level of output. Any slackening of activity which might have been experienced by modifications in the defence programme has thus been offset by the rising demand for engineering goods in the civilian market, both at home and abroad.

Thus, after serious concern about prospects in late 1952 and in 1953, the industry once again achieved something near full employment and the possibility once again appeared of inflationary pressure on prices and costs. Under such conditions, the tendency of labour is to demand a bigger slice of what looks like a larger cake. Plans for revision of the wages structure are apt to stay in pigeon-holes (if they ever even get that far) and progress which can be measured in terms other than immediate wage gains seems better kept for tomorrow.

POSITION OF THE UNIONS

It was against such a background of current economic conditions in the industry that the unions made their latest claim in December. On December 14, 1954, the Confederation of Shipbuilding and Engineering Unions followed up a decision taken at their annual conference in August and presented increase-wage demands to the Engineering and Allied Employers National Federation. The main demands have been for wage increases of 15*s.* a week for craftsmen and of 10*s.* a week for labourers. In addition to an increase in pay the Confederation is prepared to take this opportunity of introducing certain improvements in the wage structure of the industry.

They consider that in addition to the skilled and labouring grades some three of five intermediate grades should be established, each with a minimum wage rate, to provide for the constantly growing groups of men who have acquired a certain kind of skill as mechanisation has increased. In the Confederation's view, these new grades would take the place of the present vaguely defined grade of semi-skilled workers.

The existing and minimum rate for unskilled employees is £6 4*s.* 10*d.* for a 44-hour week; a corresponding rate for a skilled man is £7 4*s.* 10*d.* The gap is thus £1 a week at present, a margin which will be increased to 25*s.* a week if the claim is met. As at January, 1955, these claims are to be considered by the local associations affiliated to the employers' Federation and a further meeting between the Federation's negotiating committee and the union representatives will probably be held towards the end of this month when the employers' answer will be given.

Prior to the Confederation's decision last August to seek a wage increase, the index of wages over industry as a whole was exactly equal to the level of retail prices. In June both stood at 142, with 1947 as the base year. Between June, 1953, and June, 1954, the index of wage rates increased by 5 per cent. and the retail price index by less than 1 per cent. Over a roughly comparable period earnings in shipbuilding and ship repairing increased by 8 per cent., in marine engineering by 5 per cent.; in constructional engineering by 8 per cent. and in general electrical goods by 4 per cent.—to mention at random only a few of the engineering groups. The inference from these figures is that the earnings of engineering labour were overtaking the cost of living at that time at a fairly satisfactory rate from the point of view of the operatives. As the graph on page 74 shows, retail prices have in general moved up rather more quickly than wage rates since then, but there was only one point between the two indices at the end of October (and the gap has not moved very significantly since) so the increase in the cost of living may well have been offset by higher earnings if not by higher wage rates. A 15*s.* increase on £7 4*s.* 10*d.* is equivalent to a rise of 10 per cent. so the case for higher wages rests on other grounds than cost of living increases.

The whole issue would seem to hang on the genuineness of the desire of the Federation to negotiate a revision in the wages structure. The Court of Inquiry in September, 1948, recommended that the wages structure in the engineering industry should be overhauled as part of its suggested settlement of a wages dispute and the same point had come out of a wage dispute two years before. The inevitable tendency from labour's point of view is to raise rates at such a time, which means in effect increasing costs of production in the first instance. There is also the difficulty that broad general agreement by the two national negotiation bodies on either side of the industry may not be well received at area level on such an issue as grading. There were a number of small strikes early in 1950 in certain localities following a national wage agree-

ment. Another major problem is the difficulty of defining the engineering industry. One group of companies in the industry, notably the motor vehicle manufacturers, negotiate individual wage agreements; a second group of small companies are outside the Federation but broadly follow the Federation's wage policy. A third group is within the Federation and accepts its basic rates but has a complicated layer of incentive payments superimposed on Federation basic rates. The result is that there is apt to be disagreement about the jurisdiction of the negotiating bodies and the number of grades of labour in the industry, a difficulty which is accentuated by variations of area rates and earnings.

Perhaps one of the most significant references in the union's wage claim is the one to increased mechanisation and it is here that the problems of the present become closely related to the opportunities for the future. The trend of technical development is towards greater mechanisation, multiple shift working on expensive but highly productive machines turning out standardised goods, and the increased importance of intermediate grades of labour in the industry; these grades cannot be said to have skill in the traditional craft sense of the word but they are none the less vital for the efficient operation of the machines and acquire in time a trained aptitude which is very difficult to differentiate from actual skill. This is the importance from a technological point of view of the apparent willingness of the unions to grade labour more in keeping with the needs of an engineering age which will wish to consider labour costs in their relation to the depreciation charges and running costs of expensive plant and machinery. This does not mean that the employers will be any less inclined to bargain adroitly at the conference table, but it does mean that they will be increasingly sympathetic to sound arguments that higher wages will be accompanied by higher productivity.

The principle of this change is in fact already admitted. The question at the beginning of 1955 is how quickly this attitude of mind can percolate down through both sides of industry from the example of those who are farseeing enough to detect the new industrial revolution which is now gathering impetus.

CAPITAL INVESTMENT AND WAGES

In the first instance the amount of engineering goods installed by industry depends upon the resources which the economy as a whole is willing and able to put into new factories and machines. In 1953 the gross capital investment (including depreciation) for the country as a whole was £2,275 millions compared with £2,060 millions in 1952 (both figures being taken at 1952 prices). Rather more than half the increase in 1953 was accounted for by new housing. In 1954 the housing programme has increased slightly and the amount of resources which has been applied to other forms of fixed investment—e.g., vehicles, ships, aircraft, machinery and factories—has probably increased as well. It is likely that this upward movement in investment will gather impetus in 1955 if external factors do not interfere with the continued high level of prosperity in this country. The indications at the moment that this year will see a high level of investment, at least by recent standards, are of three kinds—the high level of factory building approved this year, the high level of savings by the community in general, and the benefits of the investment allowance granted in the last budget.

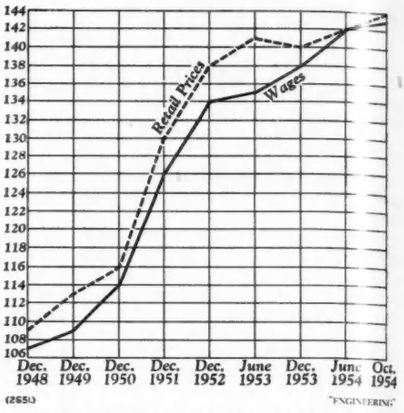
If a rate of technical advancement is to be achieved which will make it worthwhile for both labour and employers to revise the wages structure and possibly pay increasing earnings, the value of annual capital investment in this country will have to be given a considerable impetus. A high level of investment by recent standards (to quote the phrase used in the previous paragraph) is not necessarily sufficient. The gross fixed investment in this country, excluding housing, had increased from £1,411 millions in 1948 to £1,675 millions in 1950. Since then until 1954 there has been little progress however. Indeed at £1,655 millions in 1953, gross investment was at the same level as 1951 and at the lowest point since 1948.

These figures include an annual allowance for depreciation. The official figures do not make it possible to extract the annual depreciation allowance on housing so that a figure of net capital formation by the industries mentioned above is not available, but it can be inferred that since the rate of gross capital formation between 1948 and 1950 has increased by only just over £250 millions a year, whereas annual depreciation has increased by about £300 million a year, the actual rate of capital formation has declined or at the very best remained static. It would appear, in fact, that the annual rate of net capital formation in the industries listed above has declined from about £900 millions to £800 millions. It will therefore take a considerable increase in the rate of capital investment to reverse the trend and bring about a rate of installation of plant and machinery which will sustain a rate of technical improvement on which a revision of the engineering wages structure might be based.

American figures are never directly comparable with those for this country but when the gap between U.S. figures and those for this country is very big the comparison is suggestive. In 1951, which is the latest year for which a calculation is available, the United States invested £250 per worker in new plant and equipment. The corresponding figure in this country was £70. We know that the British figure has not improved between 1951 and 1953 although it is likely that the American figure of 1952 was much in excess of £250 and that it is now building up again to a still higher figure since the American recession came to an end. It would thus appear that the United States, in which the rate of progress towards a high level of mechanisation in the office and in the factory is occurring at a notably high speed, is maintaining a level of capital investment per worker probably four times as much as in this country. There is no reason to think that the comparison for industries using engineering products, if it could be isolated, would be much more favourable to this country.

It would appear therefore that an overhaul in the wages structure of the industry in this country must depend for a successful outcome on a very much higher rate of capital investment throughout the engineering industry in general. It cannot be denied that a very high level of investment in certain industries, such as vehicle manufacturing, is taking place but an uneven rate of progress in one section of the engineering industry compared with others would only complicate the problem of revising the wages structure. The unions, in calling for higher wages and a revised structure of rates are in fact calling upon the more conservative and old fashioned sections of the industry to increase their rate of investment more quickly than the more forward looking sections of it. This is a policy for the engineering industry which it is much more easy to enunciate than to put into practice, for it bristles with problems. To go no further than the initial difficulties of the investment programme, it is exceedingly difficult at a time of full employment to increase investment without cutting the demand for consumer goods which must quickly have an adverse effect on the demand for engineering goods. This would in turn destroy the incentive to invest in new plant and machinery which is just what has to be avoided. The only alternatives are to put an increased burden on exports to offset a decline in the home market or to accept as inevitable only a gradual increase in investment and a piecemeal adjustment of the wages structure.

So far as increased mechanisation is concerned, it is encouraging that there should be so much discussion at the present time about the use of electronic devices in industry, the growing use of all kinds of office equipment and the widespread discussion on the automatic factory. It is significant, too, that 1954 saw the publication of the last of the productivity reports of the



Relative movements in retail prices and wage rates since 1948. (Index: June, 1947=100.)

Anglo-American Productivity Council and that this should have been on "Industrial Engineering." In their report, which covers a wide range of subjects from production planning, control and management-labour relations to education of the industrial engineer, a good deal is said by the team on the importance of mechanisation. Speaking of achieving economy through mechanisation the report says, "We think that since the cost of labour has already increased markedly in Britain it is now more economical to mechanise than before the war and all the more essential to devote attention to improvement of methods."

ENCOURAGING PRODUCTIVITY

The confidence which American industry has in its ability to continue to expand the national economy has been shown in the growing popularity of improvement factors in wage agreements. Under such agreements, companies guarantee wage increases based on the assumption that the increase in productivity for the United States economy as a whole will be at the rate of 2½ per cent. per annum. Among companies adopting this form of mortgaging future productivity in the present interests of the operatives are foundries, electrical-equipment manufacturers, agricultural-machinery manufacturers, automobile makers, metal fabricators and constructional engineers. It does not follow automatically, of course, that the climate of industry in this country is so similar to that in America that a similar scheme would work here. It is none the less apparent that American industry, including influential sections of the engineering industry, are prepared to guarantee wage increases over a period of time because of the confidence which is engendered in boards and managements by a policy of large-scale mechanisation.

It is apparent from what has been said in previous paragraphs about the total amount of capital investment which has been taking place in this country in recent years that the engineering industry is not entirely master of its own house in the matter of capital formation. It is dependent on the policy of its user industries and they in turn, along with all other industries, are conditioned in their views in this matter by the fiscal and economic policy of the Government. There is no doubt that high taxation and the diversion of resources in the past to the provision of houses on an unprecedented scale has meant there has been less finance, and hence materials and machinery, for other industries. There were signs last year that the emphasis is changing. If good relations between management and labour are to be maintained in the engineering industry it is important that this change should be quickly accelerated.

Previous articles in this series have considered Britain's place in the engineering world. Future articles will examine the position of Britain's major engineering industries.

Book Reviews

SOCIAL SCIENCE IN THE DOCKS

The Dock Worker: An Analysis of Conditions of Employment and Industrial Relations in the Port of Manchester. THE UNIVERSITY OF LIVERPOOL, DEPARTMENT OF SOCIAL SCIENCE. *The University Press of Liverpool, Liverpool*, 3. (17*s.* 6*d.*)

Dock strikes have been the cause of more economic loss to this country since the war than any other single factor and mechanisation has probably found more resistance on dockside than anywhere else. Yet most people believe that dockers earn fabulous wages and lead lives of easy security in extreme contrast to the insecurity of their past. The thoughtless answer to this apparently ungrateful paradox is that it is all due to communist agitators, but this is not an explanation likely to satisfy experienced administrators. The true causes of human action, particularly in complex organisations, are difficult to determine and they are a comparatively new subject of scientific research.

This report is the result of a study undertaken in the Port of Manchester in 1950–51, by members of the Social Science Department of Liverpool University. It is based on a number of exploratory studies of the outlook of different groups within the industry, followed by an attitude survey of a random sample of one in seven of all the dock workers in the port. The methods of the inquiry and of its statistical analysis appear to have been very well thought out and the writing of the report is in clear, straightforward English which is a joy to those accustomed to reading much work of this kind, especially that large part of it which comes from the United States.

The conclusions of the authors substantiate much that has already been written by careful observers about this industry, including many of the findings of the Committee of Inquiry into the dock strikes of 1951. Behind it all there is the appalling history of years of casual labour during which to be a dock worker was to be considered at the bottom of the social and moral scale. It was the lives that dock workers led which gave them their well known and contradictory characteristics: their selfishness and their sense of community; their tough independence and their group loyalty; their envy and contempt of other groups in the community; and their unwillingness to accept the discipline of trade union organisation by which alone they could improve their conditions. Only if the struggles which the trade union leaders waged during the first half of this century in organising them are remembered, can their present attitude to trade union discipline be understood. Even the brilliant work of Ernest Bevin in this field, and in finally abolishing the economic insecurity of the dockers' employment, was achieved in face of much traditional opposition from dockers themselves. To-day few dock workers wish to return to the employment conditions of the past and their earnings come well up in the industrial scale. The majority of them do not, however, earn the large sums with which they are sometimes credited, because their work is, even now, on a casual basis and it is only the small payment for attendance at the call stand and the minimum weekly wage which are guaranteed.

In spite of the improvement in their conditions the report shows a very unhealthy state of industrial relations. The causes lie partly in the organisational structure of the industry and partly in the men's relations with their union, the Transport and General Workers. The creation of the National Dock Labour Corporation has confused the line of authority, so that it is now extremely difficult to say who is the men's employer. Although some degree of economic security has been provided, no change has been made in the organisation of work. About 45 per cent. of the Manchester men work most of the time in the same gangs, but these gangs are not recognised by the Area Labour Managers, who can break them up at will. The majority of men are still on a casual basis; that is to say they compete for work at the call stand just as they have always done and, in fact, the method used by the Board to allocate labour has tended to disrupt the permanent relationships established between particular foremen and certain gangs. This is a situation in direct conflict with the conditions generally held to be necessary for good industrial morale.

With the growth of formal organisation in the industry the union has become more and more concerned with the making and enforcing of agreements rather than in finding solutions to the problems and conflicts that arise daily. The union officials are out of touch with the real feelings of their members, which therefore find expression through informal (or unofficial) leaders. As the authors of the report say: "The legalistic atmosphere of public administration has obscured the realities of what is, in essence, a somewhat simple and very human situation."

The reflection, but not the cause, of this whole situation is a complete breakdown of communications between the men and their employers and the men and their union. There is no form of "on-the-job" joint consultation; chiefly because full-time officials think their own services adequate. But what the dockers want is a share in the activities of, rather than a service from, their union. One result of this lack of an adequate system of communication is that the initiation of change is made very difficult and this is one of the hindrances to mechanisation.

No doubt, those who feel most criticised by these findings will cry out that they are doing their best for the dockers and that the dockers' attitudes are unreasonable. Whether all their attitudes are unreasonable is open to question, but, even if they are, they have to be taken into account by those responsible for planning the industry. It is to be hoped that they will study seriously and without bias this important and well documented report.

Water Supply of Greater London. By H. W. DICKINSON. *The Newcomen Society, Science Museum, London, S.W.*7. (35*s.*; 25*s.* to members of the Society). Edition limited to 350 numbered copies.

To trace and record the development of the reciprocating steam engine was one of the main interests of the late Dr. H. W. Dickinson for the greater part of his long life and it was natural, therefore, that he should become equally an authority on the development and application of pumping plant, since it was for pumping water out of mines that reciprocating steam engines were initially designed. Thus, when the Metropolitan Water Board decided, towards the end of the second World War (as is explained by Mr. H. F. Cronin, C.B.E., the Chief Engineer to the Board, in a foreword to this book) that they must soon dispose of a number of their old steam pumping-engines, it was decided to ask Dickinson to record the particulars of them in a series of articles, eventually published in *The Engineer*. Dickinson, however, absorbed in his highly congenial task, added a great deal to the original conception, including much of the history of the London water companies, whose systems had been taken over by the Board, so that the articles developed into a virtual history of London's water supply as a whole.

So much material had Dickinson collected that was not common knowledge that the Council of the Newcomen Society, of which he was a founder member, a past President, and for 25 years the editor of its *Transactions*, decided to reprint the complete work in book form as a tribute to him. Unfortunately, he did not live to see its publication, but it is likely long to stand as a memorial to this most indefatigable of engineering historians. Painstaking as he was, however, the expert scrutiny of the officials of the Board, and especially of Mr. G. C. Berry, M.A., their archivist, detected a number of details requiring correction or worth amplification. Attending to these was a labour of some magnitude and considerably delayed publication, but the result is that the book now presents a more comprehensive history of the growth of London's water supply than any hitherto available, well illustrated and, of course, authoritative beyond question.

The story is traced back to the Thirteenth Century, when water first was drawn from springs and wells outside of the populated area. In the Fifteenth and Sixteenth Centuries, mechanical science had progressed to the point that it was possible to pump water from ground level to a fairly high head, by the use of water-wheels driving force pumps. In the early Eighteenth Century came the introduction of steam pumping, the first Newcomen engine in London being set to work in 1726, only 14 years after Newcomen's pioneer engine was erected near Dudley Castle. Mr. Cronin's foreword states that 68 per cent. of the water supplied to the Metropolitan Water Board's 6½ million consumers is still pumped by steam; but the internal-combustion engine entered the field in 1914, and it is now reasonably certain that no more steam engines, reciprocating or turbine, will be installed. It is rather surprising, however, to learn from this most interesting book that, while steam has been used for nearly 230 years and was the supreme source of power for pumping London's water for more than 150 years, water-wheels were the prime source for a longer period than steam has been in use, though London was one of the earliest towns to have steam-driven pumps.

German-English Technical and Engineering Dictionary. By DR. L. DE VRIES. *McGraw-Hill Publishing Company, Limited*, 95 Farringdon-street, London, E.C.4. (160*s.*)

English-German Technical and Engineering Dictionary. By DR. L. DE VRIES. *McGraw-Hill Publishing Company, Limited*, 95 Farringdon-street, London, E.C.4. (140*s.*)

(The two volumes are available as a set at the price of 280*s.*)

A subsidiary consequence of the advances that are taking place in science and engineering is the coinage of terms to describe new apparatus and phenomena. These terms are not confined to any one language; and it follows that the interchange of information depends on translations, for the accuracy of which the provision of adequate dictionaries is necessary. This being so, Dr. Louis de Vries needs no excuse for adding to the already formidable list of such volumes; and what he has done, with the assistance of a number of collaborators, must be examined on its merits and not under the charge of redundancy.

A few years ago the late Mr. P. E. Erikson laid down in ENGINEERING the criteria that a good technical dictionary should provide an ample choice of alternative meanings, since the same word may have entirely different connotations in different branches of the art. He also contended that genders should be indicated; and that the past participles of verbs, which might be used as nouns, should be included in the general index. Further, abbreviations, illustrative phrases and idioms should find a place. These views were in the main supported in subsequent correspondence and the present volumes may be analysed to discover to what extent they have been complied with.

As regards the first, and what may be regarded as the most important, requirement, these dictionaries pass, if not with high honours. As every student of German knows, the noun "Zug" has a large number of meanings; and 43 of them are given. Moreover, what is equally important, the user, who should have a working knowledge of the subject he is translating, is

left to make his choice. Genders are indicated, and what Mr. Erikson called illustrative phrases and idioms are to some extent included. On the other hand, abbreviations do not appear. This is an important omission considering the increasing use that is made of this form of shorthand. Further, a number of words are included which are not strictly speaking technical or engineering, such as " Unschuld," the sole meaning of which is innocence.

It is, of course, impossible to determine the full value of such dictionaries without constant use, but a cursory examination shows that they will be of assistance to translators in a great number of fields. To test this a recent German book on mechanics was examined and it was found that a number of words with which the reviewer was not closely familiar were adequately translated. On the other hand, while " valve " is given as one of the ten meanings of " Rohr " it is not indicated that this applies only to thermionic valves. This omission is, however, repaired in the associated compound words. There is no indication that the word " bridge " is used electrically (as in Wheatstone bridge); and to translate British Standard (sic) Institution as " Normenausschuss " is surely to generalise unduly.

These are, however, minor defects in two useful publications; and the author and his collaborators are to be congratulated on the result, which is based on the necessarily heroic work of compilation and checking. A number of new terms and expressions in such fields as electronics, rocket and jet propulsion and nuclear engineering have been included, so that the dictionaries can also be recommended on the score of up-to-dateness. The type, especially in the English-German volume, is clear and the binding is such that handling is easy, two not unimportant points.

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BOOKS RECEIVED

Some of the books noticed in the Books Received column are selected for extended review in later issues of ENGINEERING.

English-German Technical and Engineering Dictionary. By DR. LOUIS DE VRIES. *McGraw-Hill Publishing Company, Limited, 95 Farringdon-street, London, E.C.4.* (140*s.*)

German-English Technical and Engineering Dictionary. By DR. LOUIS DE VRIES. *McGraw-Hill Publishing Company, Limited, 95 Farringdon-street, London, E.C.4.* (160*s.*)

These two books are reviewed on page 75.

Audio Frequency Power Measurements. National Physical Laboratory. Notes on Applied Science No. 8. Published for the Department of Scientific and Industrial Research by *H.M. Stationery Office, Kingsway, London, W.C.2.* (1*s.*)

This publication deals with power measurements by means of electrostatic, thermal and electrodynamic wattmeters, over the range 25 to 30,000 cycles, approximately the audio-frequency range. An appendix contains a list of references to published literature on the subject.

Technical Reports of the British Electrical and Allied Industries Research Association. *Offices of the Association, Thorncroft Manor, Dorking-road, Leatherhead, Surrey.*

Some Experiments on D.C. Positive Point-to-Plane Corona Discharges. By H. M. GAUNT and J. D. CRAGGS. No. L/T294. (15*s.*) An account is given of experiments in which the light pulses emitted by direct-current positive point-to-plane corona were observed using a photomultiplier video amplifier and high writing speed oscillograph. The pulses induced at the cathode are also described and compared with the light pulses. An attempt is made to relate the light pulse with the propagation of the discharge, and to relate the induced pulse to the motion of the ions.

Review of Ferroelectricity and Antiferroelectricity in the Perovskites. By A. F. DEVONSHIRE. No. L/T298. (10*s.* 6*d.*) After a discussion of the thermodynamics of ferroelectric and antiferroelectric transitions, a short review is given of recent experimental work on ferroelectricity and antiferroelectricity in the perovskites. The relation of some of the experimental results to atomic structure is then briefly discussed.

Negative Ion Formation in Gases of High Dielectric Strength. By J. W. MARRIOTT and J. D. CRAGGS. No. L/T301. (24*s.*) This paper considers the growing use of gaseous dielectrics and gives a summary of the essential factors. Divergences in published work are noted and possible reasons given, thus leading to the consideration of attempts to correlate electric strength with some other physical parameter. Two breakdown mechanisms are considered in detail and the report goes on to describe progress to date in some of the resulting work on collision processes.

Negative Ion Formation in Gases of High Dielectric Strength. Part II: The Lozier Apparatus. By J. W. MARRIOTT and J. D. CRAGGS. No. L/T308. (15*s.*) The study of collision processes involving electrons and molecules, and their effect on the insulating properties of certain gases, as discussed in the report L/T301, is continued. Since it is believed that negative ion formation is of great importance in determining the dielectric strength of a gas and the mass spectrometer was found to be unsatisfactory for work on negative ions, it was decided to use apparatus of the type devised by Lozier. An apparatus has been constructed and a few measurements made.

The Dielectric Properties of Ketone Resins. By E. RUSHTON. No. L/T302. (12*s.* 6*d.*) The dielectric properties of pure ketone resin have been investigated over a range of temperature from −70 deg. C. to 200 deg. C., and a range of frequency from 65 cycles to 24,000 megacycles. Separate sections in the report are devoted to electrical properties and the effect of discoloration on electrical properties.

Water Sorption in Polystyrene and Cellulose Triacetate. By A. G. DAY. No. L/T309. (12*s.* 6*d.*) The Brunauer, Emmett and Teller adsorption equations are applied to results obtained for polystyrene and cellulose triacetate over limited ranges of water vapour pressure and temperature. Good empirical relationships are obtained, but there are discrepancies in the values obtained for the constant *c*. Values for the diffusion coefficients, activation energies of diffusion and heats of sorption are tabulated. Approximate values for surface sorption on polystyrene are reported and some connection between sorption and molecular weight suggested.

Cuba. Overseas Economic Survey. By P. S. STEPHENS. Published for the Board of Trade, Commercial Relations and Exports Department, by *H.M. Stationery Office, Kingsway, London, W.C.2.* (4*s.* 6*d.*)

This is a further report in the series covering economic and commercial conditions in overseas countries. It covers the period 1950 to 1954, with emphasis on the years 1952 and 1953 which saw the beginning of a new phase in Cuba, both politically and economically.

Technical Mathematics. By HAROLD S. RICE and RAYMOND M. KNIGHT. *McGraw-Hill Book Company, Incorporated, 330 West 42nd-street, New York 36, N.Y., U.S.A.* (6·50 dols.); and *McGraw-Hill Publishing Company, Limited, 95 Farringdon-street, London, E.C.4.* (52*s.*)

This is an introductory mathematics text intended for engineering technicians with about two years' knowledge of algebra. A thorough treatment of basic algebra and trigonometry is given, and these principles are applied to a wide range of specific engineering problems. One chapter is devoted to a description of and uses of the slide rule.

A Review of Productivity in the Wrought Non-Ferrous Metals Industry. *The British Productivity Council, 21 Tothill-street, London, S.W.1.* (1*s.* 6*d.*)

The review states that " Productivity in the industry as a whole has never been statistically measured," and points to the difficulties involved. However, a number of firms " have measured productivity, using yardsticks of varying accuracy." Some account of the reforms adopted is given in the Appendix, which deals with ten firms. There is a short discussion on work study and progress in workshop techniques.

Ventilating in Industry. By G. A. WILLIAMS. *The Association of Engineering and Shipbuilding Draughtsmen, Onslow Hall, Little Green, Richmond, Surrey.* (3*s.*)

This booklet contains information for draughtsmen and designers concerning the type of fan, size of trunking and standards required for industrial ventilation systems. Diagrams of ducts, tables of flow and resistance and worked examples are given and there are sections on flow measurement and air conditioning.

TRADE PUBLICATIONS

Copies of any of the following trade publications are obtainable from the addresses given, though distribution is sometimes restricted.

Portable Electric Pump. BRITISH CENTRAL ELECTRICAL CO., LTD., 6–8 Rosebery-avenue, London, E.C.1. " Flux 300 " pump, self-priming without check valves. Capacity (water and thin fluid media) 1,600 to 2,100 gallons per hour. Height of water column 12 feet. Consumption 260 watts, 220-volt supply. Explosion-proof. Illustrated leaflet.

Small Marine Vessels. THE ROWHEDGE IRONWORKS CO., LTD., Rowhedge, near Colchester, Essex. History of company with descriptions of many of the 834 vessels, from sea-going ships to sailing craft, so far launched. Illustrated booklet entitled " The Launching Years," commemorating the golden jubilee (1904 to 1954) of the Rowhedge Company.

Glass-fibre Reinforced Sheets and Tubings. THERMO-PLASTICS LIMITED, Luton-road Works, Dunstable. " Glascorein " reinforced tubes and sheets. Non-corrosive, heat resistant and dimensionally stable. High strength-to-weight ratio. Leaflet giving physical, electrical and chemical properties, and types available.

Installing Electric Sockets. M.K. ELECTRIC, LTD., Wakefield-street, London, N.18. Points to be considered when installing electric outlet sockets in the home. Leaflet (No. D.I. 1) published by the British Electrical Development Association, 2 Savoy-hill, London, W.C.2. Can be obtained from both addresses.

Portable Spray Painter. B.E.N. PATENTS, LTD., High Wycombe, Buckinghamshire. B.E.N. " Handi-spray," comprising electrically-driven air compressor, 2·58 cub. ft. per minute capacity, provided with moisture separator; B.E.N. Model 1M internal atomising pressure-feed spray gun; three interchangeable nozzles. Illustrated leaflet.

Electronic Equipment. F. C. ROBINSON & PARTNERS, LTD., 287 Deansgate, Manchester 3. Stabilised power-supply units, control equipment, high-speed cathode-ray tubes, special test instruments, amplifiers, signal generators, etc., for research, development and production. Illustrated booklet, general in nature.

Filters and Strainers. G. & A. FIRKINS, LTD., 84 Darlington-street, Wolverhampton. " Firtop Y Pattern " strainers for normal protective duties; " Firtop " pack-type filters for filtration down to 1½ microns; sizes and dimensions. Illustrated leaflet.

Screwing Taps. C. E. JOHANNSON, LTD., Southfields-road, Dunstable, Beds. The manufacture and use of screwing taps; comprehensive tables of thread sizes, tolerances, and other dimensions relating to screwing taps for British and American practice. Illustrated book.

Temperature Control for Air Conditioning. THERMO-CONTROL INSTRUMENTS CO., LTD., 2–10 Valentine-place, London, S.E.1. Electronic temperature-control equipment using Thermistor detectors and compensated for outdoor temperature. Leaflet gives details.

Time Recorders and Works Signalling. GENERAL SIGNAL & TIME SYSTEMS, LTD., 73 Great Peter-street, London, S.W.1. Autograph time recorders, job costers, master and slave clocks, staff location systems, light signals, industrial radio. Two illustrated leaflets.

Electronic Metal Detector. METAL DETECTION, LTD., Moseley-street, Birmingham, 12. Equipment for detecting tramp metal in a variety of materials by a high-frequency electromagnetic field. Illustrated leaflet.

Welding Transformer. MAX ARC & ELECTRICS LTD., Terrace-road, Walton-on-Thames, Surrey. Oil-cooled welding transformer, output 300 amperes, continuous rating, 12 kVA. Leaflet gives details.

Welding Controllers. BATES & BATES LTD., 73 Ashville-avenue, Birmingham 34. Electronic contactors, regulators and timers for resistance welding. Booklet of uses and types available.

Feeler Gauge. RUBERT & CO. LTD., Chapel-street, Manchester, 19. Feeler gauge with protected blades and patent dispenser; list of sets available. Illustrated leaflet.

Caliper Gauge. BROOKS & WALKER LTD., 47 Great Eastern-street, London, E.C.2. " Reynard " adjustable limit plain caliper gauges; range from 0 to 6 in. Illustrated leaflet.

Grease Nipple Protection Caps. G.N.P.C., Kelsale, Saxmundham, Suffolk. Grease-resistant rubber caps for protecting grease nipples. Leaflet.

BRITISH STANDARDS

The following publications have been issued by the British Standards Institution. Copies are available from the Sales Department of the Institution, 2 Park-street, London, W.1, at the price given after each title.

Glossary of Terms and Notation for Toothed Gearing. (6*s.*, post free).

A new British Standard glossary (B.S. 2519), gives definitions for terms commonly used in all applications of toothed gearing. It also gives a standard notation which includes symbols suitable for use in the theory and practice of gear engineering. The terms and definitions are grouped in eight sub-sections referring, respectively to types of gears, geometrical terms, general definitions, terms relating to surfaces, linear and circular dimensions, angles in gear engineering, factors, and errors in gear cutting. There is a complete index and 20 pages of line drawings. No attempt has been made to produce a text-book, but the committee responsible have endeavoured to include all the terms required for practical use.

It is intended that, in future, specifications for gears will include only the special terms and symbols applicable to the particular type of gearing covered by the publication.

Polythene-Insulated Cables (sheathed with P.V.C., for electric power and lighting up to 250 volts.) (5*s.*, post free.)

A new edition of B.S. 1557, covering polythene-insulated cables sheathed with polyvinyl chloride has now been published. It supersedes that issued in 1949, and the principal new feature is the reduction in insulation and sheath thickness which has been found possible as a result of experience. Other changes are the inclusion of quality requirements and tests for the P.V.C. sheath and a method for the determination of the grade of the polythene insulation. It has been considered desirable to specify tinned-copper conductors as standard, the main advantages being ease of jointing and resistance to corrosion. The standard reference temperature of 20 deg. C. has been adopted as in other recent specifications for cables. It should be noted that the 250-volt cables specified are deemed to be suitable for use on a three-phase, 440-volt system having its neutral part solidly earthed. A method for the determination of the grade of the polythene insulation has been included.

Stiffnuts for Aircraft (10*s.* 6*d.*, post free.)

A series of specifications, A.125 to A.168, issued under one and the same cover, stipulate the dimensions, materials, testing and identification requirements for aircraft stiffnuts of $\frac{1}{4}$-in. nominal size, and above, with Unified (UNF) threads. A "stiffnut" is defined as consisting of a nut body surmounted by a device to impose friction between the nut and the screw thread on which it is mounted, to such a value that the nut may be considered self-retaining. The friction is required to be independent of the loading on the face of the nut.

The new standards consolidate, in one series of publications, the information previously contained in specification AD. 114, published in 1942 by the Royal Aircraft Establishment, and setting but the design and test requirements for proprietary stiffnuts; the Ministry of Supply A.G.S. drawings, which provided common part numbers, maximum envelope dimensions and other features affecting interchangeability, and, finally, individual manufacturers' drawings. The preparation of the standards afforded, moreover, an opportunity to co-ordinate the development of a new series of nuts, the incorporation of which has resulted in more comprehensive specifications than had been possible hitherto.

The steel (including corrosion-resisting steel), brass and bronze, and aluminium-alloy nuts covered by the standards are capable of functioning satisfactorily at sustained temperatures of 200 deg., 150 deg., and 125 deg. C., respectively. All the nuts are capable of remaining effective for service operations at −40 deg. C. and are satisfactory for use at −75 deg. C. Numerous drawings are included.

Radio Equipment. (Sizes and forms for civil aircraft.) (7*s.* 6*d.*, post free.)

The first of a new series of specifications dealing with radio equipment for civil aircraft has now been issued. The specification, R.1, prescribes standard dimensions for radio units and subsidiary units and their associated racking. Standard forms of construction are prescribed in conjunction with standard methods of connection using plugs and sockets. The standard does not deal with performance requirements and is divided into five sections dealing with rack-mounted units, rack mountings, subsidiary units, the marking of units and the colour and finish of units. Fifteen line drawings with dimensions and other data are included.

TRENDS IN ELECTRIC LOCOMOTIVE DESIGN*

By G. V. Davy, B.SC. (ENG.), A.M.I.MECH.E., A.M.I.E.E.

Direct-current electric locomotives could, 20 years ago, be divided into low and high speed types. The former were often of the bogie variety and the latter of the rigid frame type with guiding bogies or pony axles. The bogie type locomotives were usually driven through solid gears by nose-suspended motors and tended to be restricted to medium speeds. The size of the individual motors was something under 400 h.p. On the high speed locomotives the motors were spring-borne in the superstructure, various methods of drive being employed.

Since the war there has been a tendency to build both high speed and powerful locomotives of the bogie type. Where the top speed is about 75 m.p.h. nose-suspended motors, which are only partially spring-borne, are now employed. The motors have individual outputs of 600 h.p. at 3,000 volts on a 3 ft. 6 in. gauge. For the higher speed locomotives bogie-mounted motors with outputs of over 1,000 h.p. and entirely spring-borne are commonly used.

A DRIVE PROBLEM

The nose-suspended motor has the advantages of being simple, cheap and long-lived and the disadvantages of stressing the track and of passing shocks to the armature. It is often used in conjunction with resilient rubber gear wheels to provide flexibility. The advent of the high-powered bogie-mounted and entirely spring-borne motor has necessitated the development of drives transmitting to wheels of comparatively small diameter and installed in a confined space. The problem is to drive an axle with both vertical and lateral movements from a rigidly mounted motor. Various solutions have been evolved, including the Brown Boveri disc and spring drives and the Alsthom drive.

CONSTRUCTIONAL DETAILS

Bogies for locomotives with nose-suspended motors have changed to a relatively small degree, although it is now unusual for them to be articulated. Welding is used to a greater extent, but some cast steel frames are employed. To minimise the effects of weight transfer the motors are carefully arranged in the bogie and equalising beams are utilised.

On the high-speed high-powered locomotives with totally spring-borne motors, such as those used on the French and Netherlands Railways, the body is attached to the bogie by two swing links pivoting on conical rubber seatings, in the bolsters between the traction motors. Two spring assemblies exert transverse forces to restore the pivot to the vertical. The axleboxes are attached to the bogie frame by short rods mounted on Silentblocs. When subjected to vertical displacement the rods give and the Silentblocs are twisted; and to compensate for the decrease in the horizontal length of the rods the axlebox rotates very slightly. Under lateral thrusts the Silentblocs are compressed and give reactions in the region of 10 tons for each 0·2 in. displacement. To protect the motors from lateral shocks they are attached transversely to the bogie frame by rod-mounted Silentblocs. Rubber is used where pivoting takes place and reduces maintenance.

The tendency is to use all-welded underframes and superstructures, in which the side members of the latter form a truss section to increase the overall rigidity and resistance to buffing stresses. Pressings and extruded sections are employed in place of standard steel sections with a saving in weight and no loss of strength. As the motor has to fit between the bogie frames, and the diameter of the wheel is limited, its size is correspondingly circumscribed.

* Paper read before the Institution of Locomotive Engineers on Wednesday, January 12, 1955. Abridged.

FRENCH LOCOMOTIVE DESIGN

During the last 30 years the horse-power of the Bo-Bo locomotives used on the French Railways has increased from 920 h.p. to 4,000 h.p. and their weight from 72 to 80 metric tons. Until 1938 the maximum speed was about 90 km.p.h. It was then raised to 105 km.p.h. by the use of the resilient gears. The latest locomotives, with totally spring-borne motors, are capable of 160 km.p.h. Advances in motor design have enabled the weight of the 2-D-2 locomotives to be reduced and by employing the Co-Co wheel arrangement the same horse-power and better characteristics have been obtained with a lower maximum axle load. With the increase in the capacity of the individual motors there has been a great increase in performance over extended speed ranges. The locomotive characteristic has been improved by weakening the field strength in the series, series-parallel and parallel groupings; and it has been found possible to reduce the percentage of full field strength on which a motor will run safely. As this weakening has limitations imposed by the electrical stability compensating windings have been introduced.

On the 4,000-h.p. 2-D-2 locomotives, which have a total weight of 144 metric tons, field weakening caused the adhesive weight of 81 tons to be the limiting factor in using the high-speed end of the characteristic. To increase this weight, a change to six motors was necessary and a Co-Co type of similar horse-power, but weighing 102 metric tons, all of which were adhesive, has been designed.

CONTROL GEAR

As regards control gear, there is a growing tendency to use electro-pneumatic contactors for resistance switching and cam groups for transition from one motor grouping to another. Reductions in weight and bulk have been effected by the use of strip-metal resistances in place of cast iron. The total number of running notches has increased with the advent of general purpose locomotives. Groups of apparatus are usually mounted in separate frames so that individual contactors and relays or complete frames can be quickly removed, thus facilitating maintenance. For the same reason, control wiring is now commonly bundled on jigs and connected to terminal boards. Weight is saved by running the power cable in thin-section copper conduit. The air control apparatus is also grouped on a frame. The moving parts of pantographs have been reduced in weight so that they respond quickly to variations in line height.

While the well-known principles of motor grouping have been adhered to on the majority of direct-current locomotives, an attempt has been made to reduce the bulk of the field shunt resistances by a combination of field tapping and shunting. Some thought has also been given to the use of series and compound motors with separately-excited series fields. Tests have shown that the compound motors gave a wider economic speed range at lower tractive efforts than plain series motors, as well as close speed control and automatic regeneration.

ALTERNATING-CURRENT LOCOMOTIVES

The design of $16\frac{2}{3}$-cycle locomotives has generally followed that of their direct-current counterparts in regard to wheel arrangement and motor mounting. In early designs the motors were installed in the superstructure and drove the wheels through rods and jack-shafts;

this arrangement was not completely satisfactory at very high speeds, and the next development was one in which the motor was frame-mounted and drove the axle in such a way as to allow of relative movement between the two. The locomotive still had leading and trailing idling bogies and driving axles, so that only part of the total weight was adhesive. Decreases in the weight and dimensions of the electrical equipment have enabled bogie-mounted fully spring-borne motors to be used in sizes up to 1,250 h.p.

The horse-power of 16⅔-cycle single-phase motors has been higher than that of their direct-current counterparts, owing to the relatively unlimited space for the rod drives and the fact that starting is the greatest limitation. Commutation and heating are two difficulties which have given trouble in the evolution of the motor, but once the former had been solved the weight fell from 19·5 lb. per horse-power in 1925 to 7·8 lb. per horse-power in 1945. This decrease has been achieved by raising the armature and commutator peripheral speeds, by improving the insulation, the cooling, the commutators and the magnetic quality of the steel.

The bogie of the Swiss Locomotive and Machine Works locomotive is a departure from usual practice, but the design of the underframe and superstructure is generally similar to that for direct-current locomotives. As regards the electrical equipment the main oil switch has been replaced by a fuse on the roof and on high-powered locomotives an air-blast circuit-breaker has been used. Both these changes have resulted in a reduction in weight and fire risk. High-tension control is now commonly employed and the weight of the transformer has been reduced by using a central core and radial laminations. The tap changer can be controlled by mechanically-operated switches.

EMPLOYMENT OF INDUSTRIAL SUPPLY FREQUENCY

The use of industrial supply frequency for traction purposes dates back to 1898 when three-phase current at 750 volts 42 cycles was employed on the Berthoud-Thoune line in Switzerland. Later, the 10,000-volt three-phase system was introduced in Italy, but had the disadvantages of double contact lines and a limited number of fixed speeds. Single-phase current at 15,000 volts and 50 cycles was employed on the Seebach-Wettingen line in 1904. Single phase/three phase locomotives, operating at 15,000 volts and 50 cycles, were introduced on the Hungarian Railways in 1933 and in the same year the Hollental line in Germany was electrified at 20,000 volts 50 cycles. In 1950, another type of single phase/three-phase locomotive, usually known as the Ganz, began operations in Hungary.

ALTERNATIVE METHODS

There are three other major ways of utilising industrial frequency: by employing a single phase/direct-current motor-generator to supply direct-current motors; by using a rectifier to supply the direct-current; and by supplying alternating current direct to the motors. Once the weight of the converters has been reduced the first of these methods showed several advantages from the point of view of control; and the co-efficient of adhesion is better than that of direct-current locomotives or those with single-phase motors. The starting characteristics are also better than those of single-phase motors.

The great advantage of employing rectifiers is the reduction in weight, compared with that of a motor-generator set. For example, the Valenciennes-Thionville locomotives have rectifiers weighing only 5·8 tons, compared with the 15 tons of the converter set of the 3,280-h.p. Annecy locomotive. As regards control this type of locomotive has the same advantages as one with a motor-generator.

Although it is not possible to reach definite conclusions regarding future trends it appears that a proportion of entirely new electrifications will be carried out on the high-voltage single-phase industrial-frequency system. Existing systems, such as 3,000-volt direct-current, will, however, continue to be used where traffic and other conditions show it to be more suitable.

It is too early to say whether there will be any general trends towards one particular type of single-phase locomotive. All existing types have their advantages and disadvantages. The 50-cycle commutator motor seems capable of improvement, particularly in regard to commutation and brush wear. The direct-current motor supplied from a rectifier is possibly the best way of using single-phase current as it does away with the necessity for rotating plant.

ROCKET MOTOR OXIDANTS

HYDROGEN PEROXIDE OR LIQUID OXYGEN?

The relative merits of hydrogen peroxide and liquid oxygen as oxidants for liquid-propellant rocket motors were discussed at a meeting of the British Interplanetary Society in London on January 8. The case for hydrogen peroxide was stated in a lecture entitled "Using Hydrogen Peroxide," given by Mr. A. V. Cleaver, chief engineer of the Rocket Motor Division of the de Havilland Engine Company, Limited; this was followed by "Liquid Oxygen as a Rocket Propellant," by Mr. S. Allen, chief engineer of the Rocket Motor Division of Armstrong Siddeley Motors Limited. (To assist readers not familiar with the properties of rocket propellants, Tables I and II give the physical properties and performance data for the three principal oxidants that have been used up to the present in rocket motors.)

TABLE I.—*Physical Properties of Oxidants*

	Specific gravity	Freezing point, deg. C.	Boiling point at 1 atm., deg. C.
Liquid oxygen	1·14	− 218	− 183
H.T.P. (85 per cent.)	1·37	− 17	Decomposes
Nitric acid	1·52	− 42	86

TABLE II.—*Performance Data for Various Oxidants with Kerosine.*
Chamber pressure, 20 atmospheres.
Expansion ratio, 20 to 1.

—	Mixture ratio, oxidant/ fuel by weight	Mixture mean specific gravity	Combustion temperature, deg. C.	Specific thrust, lb./lb./ sec.	Impulse/ volume, lb. sec./ ft.³
Liquid oxygen	2·25	1·02	3,000	250	15,900
H.T.P. (85 per cent.)	8·5	1·28	2,300	230	18,400
Nitric acid	5	1·4	2,600	230	20,100

HYDROGEN PEROXIDE

In practice, Mr. Cleaver said, the available oxidants were limited to hydrogen peroxide, liquid oxygen and nitric acid. Hydrogen peroxide had many advantages over the other two oxidants, particularly for naval and aircraft applications. It was now produced on a large scale in concentrations up to 90 per cent., commonly known as high test peroxide (H.T.P.), and was highly stable. Th present cost of 85 per cent. H.T.P. was about £150 per ton, but new production methods were being investigated which might halve the cost.

Fuels for use with H.T.P. could either be self-igniting with the liquid H.T.P.—e.g., the fuel known as C-stoff used by the Germans in the Walter 109-509 rocket motor which powered the Messerschmitt 163 interceptor aircraft—or non-self-igniting, such as kerosine and petrol, which needed an ignition flame to ignite them with liquid H.T.P. The latter could, however, be decomposed by certain catalysts into steam and oxygen at a temperature of several hundred degrees Celsius, affording a much safer method of ignition.

THERMAL IGNITION MOTOR

In a rocket motor of this type—known as a "thermal ignition" motor—the H.T.P. was decomposed by a suitable metal screen (tin, lead, silver and copper were some readily available catalysts) and the fuel was sprayed into the resultant "steam." With a suitably chosen pressure, ignition was spontaneous. Whereas in a motor relying on spontaneous ignition of the liquids or ignition by a flame or electric spark, the leakage through a faulty valve could allow one or both propellants to accumulate with a consequent explosive ignition and a high risk of wrecking the combustion chamber, in a thermal ignition motor any accumulated fuel would be purged before the self-ignition pressure had been reached. Further advantages were the simplicity of the system and the fact that half thrust could be obtained from the H.T.P. alone in the event of the fuel system failing to operate.

H.T.P. had in fact been used as the sole propellant in several rocket units, e.g., the de Havilland Sprite. Although simple to design and operate, the free oxygen was lost, and therefore decomposed H.T.P. steam was more often used as an auxiliary drive than as the sole rocket propellant. In many rocket units the propellants were pumped by means of centrifugal pumps driven by a small steam turbine and for this use H.T.P. was ideal. It had been used thus in the Bell X1 and Douglas Skyrocket research aircraft, and the Martin Viking high-altitude research rocket.

AVOIDING DECOMPOSITION IN STORAGE

For long-term storage of H.T.P. pure aluminium was desirable to keep decomposition to a minimum. (For short-term storage many aluminium alloys and stainless steels were satisfactory). Under normal temperate storage conditions a drop in concentration of about 1 per cent. per annum could be expected, which would rise to 2 or 3 per cent. under tropical conditions. Tanks thus needed venting, and because of the danger from catalytic contaminations such vents needed careful design. In the event of a small amount of contamination the bulk temperature of the H.T.P. would rise somewhat but the addition of a stabiliser could arrest the decomposition. With rapid decomposition the only remedy was dilution with water down to 50 per cent. or less, at which concentration it was quite harmless. Under the worst conditions a pressure burst could occur, but no trouble due to contamination had been encountered by the de Havilland company. Detonation, which had at one time been thought to be a risk, was possible only under the most severe laboratory conditions.

For several years H.T.P. had been handled quite safely by industrial personnel with very little training. As with all powerful oxidants there was a fire risk; H.T.P. falling on to organic matter, in particular wood, paper, dirty cloth, etc., decomposed, and if sufficient liquid were present ignition could occur. Thus, cleanliness in handling was essential, and water must always be available to dilute any accidental spillages. Polyvinylchloride protective clothing and face visors must always be worn by operators during handling operations. Any accidental intimate mixture with a hydrocarbon was a potential explosive risk, and thus all equipment, cowlings, etc., had to be kept clean, and self-contained equipment with self-sealing couplings used for transfer purposes.

H.T.P.: ADVANTAGES FOR FIGHTERS

The design of rocket motors using H.T.P. was generally much simpler than with other oxidants, particularly because of the much lower combustion temperatures obtaining. In the field, H.T.P. had a big advantage in that the vehicle

Filling the liquid-oxygen tank of the Hawker P.1072 aircraft, which was powered by a Snarler rocket motor.

could be filled and left to stand for a considerable period of time. This was not possible with liquid oxygen. On the basis of performance per unit weight of mixture with a given fuel, H.T.P. was inferior to both liquid oxygen and nitric acid. However, on a volume basis it gave a better performance than liquid oxygen, in some instances an advantage. For example, in a fighter installation the tank volume for a given total output would be nearly 20 per cent. higher for a liquid-oxygen installation than for the equivalent H.T.P. installation. In addition allowance must be made for the insulation on the liquid-oxygen tank, resulting in a higher structure weight and drag.

LIQUID OXYGEN: LOW COST, LOW BOILING POINT

One of the main attractions of liquid oxygen, Mr. Allen said, was its low cost, about £10 to £20 per ton at present; its main disadvantages was the boiling point, − 183 deg. C. This cost could be further reduced in the future if the rocket industry absorbed very large quantities, but even the present figures were in striking contrast with the cost of H.T.P.

On account of its low boiling point liquid oxygen was continually boiling off. For large ground-installation tanks (80 tons capacity) losses could be reduced to 0·6 per cent. per day, and on the latest 8-ton-capacity road tankers the loss was 3 per cent. per day standing and 4 per cent. per day when moving. These losses were not important, because of the low cost of the liquid oxygen. In an aircraft or missile, however, only a small amount of lagging could be used because of its weight and bulk.

A typical case was that of an aircraft tank holding 600 gallons of liquid oxygen. The tank, including 1-in. thickness of insulation, weighed 300 lb. and the loss rate was 3 per cent. per hour. By using vacuum insulation the rate could be reduced to ½ per cent. per hour but only by doubling the tank weight. Due to the heat capacity of the tank there was a further loss on filling amounting to 4 per cent. However, by super-cooling by 10 deg. C. the filling losses could be reduced almost to zero and the tank could stand for 80 minutes before the temperature rose to boiling point. The loss on standing could be important for, say, interceptor aircraft, which had to be at the " ready " for considerable periods, but whether or not the cost of super-cooling equipment would be justified would depend on a complete analysis of the conditions.

SAFE TO HANDLE

Handling was easy and safe provided certain elementary precautions were taken. The liquid was not poisonous or corrosive but could cause severe frost-bite, and therefore asbestos gloves had to be worn during all handling operations, otherwise no special clothing need be worn. No spontaneous fires could be started, but if a fire occurred it would be vigorous. Safety precautions were therefore as for petrol. A trouble that occurred with liquid oxygen but not with H.T.P. was the evaporation of liquid locked-up between closed valves, which could cause burst pipes. Hence all lines were drained and safety devices were provided.

The performance on a weight basis with a given fuel was higher than with any other oxident except fluorine and liquid ozone, which could be discounted for practical purposes since fluorine cost £6,000 per ton and was highly poisonous and corrosive, and liquid ozone was available in laboratory quantities only. The high combustion temperature made combustion-chamber design more difficult. (In the discussion Mr. Cleaver pointed out that in order to run at a safe temperature present-day liquid oxygen motors could not run on optimum mixture ratio and consequently, he said, there was little difference between the performance of liquid oxygen and H.T.P. motors even on a weight basis.)

DESIGN PROBLEM

The only constructional metal to be avoided was mild steel, which became extremely brittle at low temperatures. Sealing materials were mostly brittle at liquid-oxygen temperatures, but water-dressed leather impregnated with beeswax had been found to be very satisfactory. Trouble had been experienced in the use of aluminium in pumps. On one occasion rubbing had occurred which had raised the aluminium to self-ignition point in oxygen, and an explosion had resulted. All surfaces which might under some circumstances rub were now made from stainless steel or bronze. (Some of these problems encountered in developing the Snarler rocket motor were described in an article in the September 17, 1954, issue of ENGINEERING, p. 374, vol. 178.)

The pressures throughout the system had to be arranged so that any temperature rise did not bring the liquid to its boiling point at that pressure. An exception was allowable in the Snarler rocket motor in the feed line from the tank to the pump. In this motor a screw booster was used as the first pump stage, and since this type of pump could swallow a certain amount of gas, boiling was allowed.

With all normal fuels electrical or pyrotechnic ignition was required. Safety could be obtained by igniting only a small percentage of the total flow in a pilot chamber and passing the gas from this into the main chamber. The pressure actuated a switch which allowed the entry of the main propellants which were then ignited by the pilot-chamber gases.

In all rocket-motor testing the measurement of propellant flow-rates and liquid oxygen had given a great deal of trouble. No suitable flowmeter had been available when the Armstrong Siddeley company had commenced work, and they had had to develop their own for a flow rate of 6 lb. per sec. It consisted of a light-alloy bladed rotor mounted axially in the pipeline on miniature ball bearings. On one blade was embedded a small piece of magnetic steel. An external pick-up coil received a signal at each revolution and the output from the coil was a measure of the flowrate.

DANGERS OF NITRIC ACID

In the discussion that followed the speakers were asked about the suitability of nitric acid as an oxidant. Both speakers agreed that the difficulty of handling was very much against it, particularly for aircraft applications, although it had been fairly widely used in the United States. A slight leakage in an aircraft could easily prove fatal because of its highly corrosive properties, whereas a slight leakage of either H.T.P. or liquid oxygen was unlikely to be dangerous. Long-term storage was difficult especially outside the temperate zones, although it could be stored in sealed containers for a certain period. One possible application for nitric acid was in the anti-aircraft missile where the missile could be filled and stored ready for operation.

In reply to another questioner Mr. Cleaver said that the comparatively high freezing point of H.T.P. was not likely to cause undue trouble in aircraft operations. In temperate conditions it would be liquid in storage, and the comparatively short time during which it would be exposed to low temperature at altitude would not cause freezing. Under more severe climatic conditions arrangements could easily be made for heating the storage tanks to prevent freezing.

* * *

LAUNCHES AND TRIAL TRIPS

M.S. " PINEMORE."—Single-screw cargo vessel with accommodation for twelve passengers, built by the Burntisland Shipbuilding Co., Ltd., Burntisland, Fife, for the Johnston Warren Lines, Ltd., Liverpool (Managers: Furness, Withy & Co., Ltd., London, E.C.3). Vessel designed for the carriage of citrus fruits and general cargo between East Mediterranean ports and the United Kingdom. Main dimensions: 345 ft. between perpendiculars by 52 ft. 7 in. by 32 ft. 4 in. to shelter deck; deadweight capacity, 4,900 tons on a draught of 21 ft. 9⅛ in. Hawthorn-Doxford four-cylinder opposed-piston Diesel engine developing 3,300 b.h.p., constructed by Hawthorn Leslie (Engineers) Ltd., Newcastle-upon-Tyne, and installed by the shipbuilders. Engine arranged to burn heavy-fuel oil. Launch, December 28.

M.S. " VASSIJAURE."—Single-screw oil tanker and ore carrier, built and engined by the Götaverken Shipyard, Gothenburg, Sweden, for Trafikaktiebolaget Grängesberg-Oxelösund, Stockholm, Sweden. Main dimensions: 595 ft. 6 in. overall by 74 ft. 6 in. by 44 ft. 3 in.; deadweight capacity, about 21,700 tons on a mean summer draught of 31 ft.; oil or cargo capacity, 805,000 cub. ft. Götaverken nine-cylinder single-acting two-stroke Diesel engine, developing 6,750 b.h.p. at 112 r.p.m., and arranged for burning heavy oil. Speed, 14½ knots, fully loaded. Delivered, December 29.

M.S. " CEDARBANK."—Single-screw cargo vessel, built and engined by Harland and Wolff, Ltd., Belfast, for the Andrew Weir Shipping and Trading Co., Ltd., London, E.C.3. Main dimensions: 425 ft. between perpendiculars by 59 ft. by 38 ft. 3 in. to shelter deck; gross tonnage, 5,671. Fourth of a series of six vessels for these owners. Harland-B. and W. six-cylinder single-acting two-stroke Diesel engine. Trial trip, January 5.

M.S. " STEYNING."—Single-screw cargo vessel, built by Austin and Pickersgill Ltd., Sunderland, for Stephenson Clarke Ltd., London, E.C.3. Main dimensions: 231 ft. by 38 ft. 2 in. by 16 ft. 6 in. to upper deck; deadweight capacity, about 2,000 tons on a mean summer draught of 15 ft. 9 in. Clark-Sulzer eight-cylinder single-acting two-stroke trunk-piston oil engine, constructed and installed by George Clark (1938) Ltd., Sunderland. Service speed, 10¾ knots. Launch, January 6.

THE ULTIMATE STRENGTH OF THICK-WALLED CYLINDERS SUBJECTED TO INTERNAL PRESSURE

1—APPARATUS FOR PRODUCING VERY HIGH PRESSURES

By B. Crossland, M.SC., PH.D., A.M.I.MECH.E., A.F.R.AE.S., *and J. A. Bones*, B.SC., G.I.MECH.E.

There are several formulae for assessing the ultimate strength of thick-walled cylinders subjected to internal pressure. This article, to be published in two parts, describes tests the authors have carried out to provide the accurate experimental evidence required to establish the validity of these formulae. It gives the authors' conclusions on these formulae, and it describes an apparatus developed for producing very high pressures (46 *tons per square inch*).

A thick-walled cylinder will be taken as a cylinder having $K > 1{\cdot}2$, where K is the initial ratio of external to internal diameter. This article deals with ductile thick-walled cylinders with closed ends so that under internal pressure the cylinder wall is subjected to axial stress in addition to tensile hoop and compressive radial stresses.

Fig. 1 shows a typical pressure/expansion curve for a thick-walled cylinder, and illustrates the phases of the behaviour of the cylinder as the pressure is increased steadily. From O to A the cylinder is elastic and at A yield occurs at the bore. Between A and B the cylinder becomes completely plastic and strain-hardening occurs, the shape of the curve depending on the properties of the material in shear and the value of K. It must be noted that from O to B the strains are independent of the axial position of the plane of measurement. At B a point of instability is reached and localised bulging occurs: the pressure at B is the ultimate pressure of the cylinder. This is analogous to the necking in a tension specimen at the ultimate tensile stress. The cylinder ruptures at some lower pressure at C.

EQUATIONS FOR ULTIMATE STRENGTH

Cook and Robertson[1] tested nine mild-steel thick-walled cylinders in the limited K ratio range from $K = 1{\cdot}35$ to $K = 1{\cdot}79$. They compared their results for ultimate pressures with the experimentally-determined ultimate tensile stress of the cylinder material, and found that the relation

$$\frac{p}{f} = \frac{K^2 - 1}{K^2 + 1}, \quad . \quad . \quad (1)$$

where p = ultimate pressure

f = ultimate tensile stress,

fitted their results fairly closely, though it was admitted that this was an empirical result for which there was no rational foundation.

Cook and Robertson used a form of thick-walled cylinder having a central parallel part of the desired K and ends of greater K. They investigated the strengthening effect of the ends and concluded that the ultimate pressure was unaffected when the length of central part of the specimen exceeded four times its external diameter.

Manning[2] gave a method of deriving the ultimate pressures of ductile thick-walled cylinders from the results of a torsion test. The theory is based on the assumption that the relationship between maximum shear stress and strain in a cylinder is identical with that in a circular specimen under torsion for all deformations. Since the results of a torsion test can readily be interpreted in terms of maximum shear stress and strain all the way to failure, the behaviour of the thick-walled cylinder can be predicted right up to the ultimate pressure. The theory assumes also that: (*a*) for overstrained ductile material, deformation takes place at constant volume, and (*b*) the axial strain is always negligibly small. In support of (*b*) he was unable to give strong experimental evidence. Manning showed that the Cook and Robertson results supported the theory, but this was of doubtful validity since Cook and Robertson had published no torsion test results for their cylinder material, and Manning had to assume an average torsion curve for mild steel in calculating the theoretical results.

Manning's theory for determining the ultimate pressure cannot be expressed in a single equation. To find the ultimate pressure it is necessary to calculate the pressure/expansion curve, for which a numerical or graphical integration is required. A resumé of the theory described by Manning is given in an Appendix which will be published with the second part of this article.

Blair[3] proposed a formula for the ultimate pressures of thick-walled cylinders based on an extension of the strain-energy theory which he claimed agreed more closely to the Cook and Robertson results than did equation (1). Blair's formula is:

$$\frac{p}{f} = \frac{(K^3 - 1)}{\sqrt{\frac{3}{2} + K + \frac{1}{2}K^3 + K^4}}. \quad (2)$$

As Professor Morrison's letter on this article showed, Blair's theoretical derivation of equation (2) was completely invalidated by the inaccuracy of his assumptions for the stress distributions in an overstrained cylinder, and Blair himself states that in deriving (2) he chose Poisson's ratio = $\frac{1}{4}$, instead of the generally accepted value of $\frac{1}{2}$, not from theoretical considerations but only because it gave an answer which fitted the test results more closely. Formula (2) thus becomes no more than another empirical formula. Blair suggested that for estimating ultimate pressures the mean-diameter formula

$$\frac{p}{f} = \frac{2(K - 1)}{K + 1}, \quad . \quad . \quad (3)$$

is sufficiently accurate.

Faupel and Furbeck[4], without strong theoretical foundation, proposed the formula

$$p = \frac{2y}{\sqrt{3}}\left(2 - \frac{y}{f}\right)\log_e K, \quad . \quad (4)$$

where y = plastic yield stress in tension.

Their tests on eight steel cylinders having K between 2·5 and 2·75 and in various conditions of heat treatment gave ultimate pressures which were within − 19 per cent. and + 11 per cent. of those predicted by equation (4).

Deffet and Gelbgras[5] have also carried out ultimate pressure tests on cylinders of mild and medium carbon steels, having a K from 1·48 to 2·467. They compared their results with values predicted by the Cook and Robertson equation (equation 1) and an empirical equation proposed by van Iterson[6]:

$$\frac{p}{f} = \log_e K. \quad . \quad . \quad (5)$$

Their results, which show considerable scatter, do not support either of these equations.

The tests described in this article were designed to provide the accurate experimental evidence required to establish the validity of these ultimate pressure relations.

The first requirement of these tests was that thick-walled cylinders having a wide range of K should be tested, particularly cylinders with large K because then the various theoretical results are significantly different. It was necessary to measure the axial strain in the cylinders right up to ultimate pressure in order to verify, or otherwise, Manning's second assumption. In addition, careful tests on the material used for the cylinders were required in torsion, to give the complete shear-stress/shear-strain curve, and in tension, to give the plastic yield stress and the ultimate tensile stress.

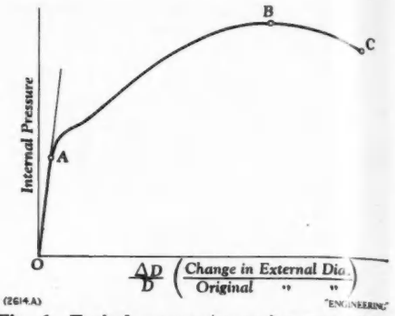

Fig. 1 Typical pressure/expansion curve for a thick-walled cylinder subjected to internal pressure.

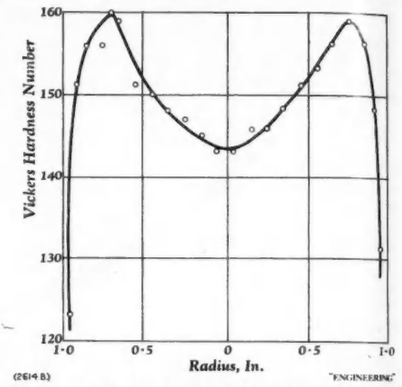

Fig. 2 Variation of hardness across the annealed bar used for the test specimens. The effect of this variation was allowed for by careful positioning of the specimens when cutting them from the bar.

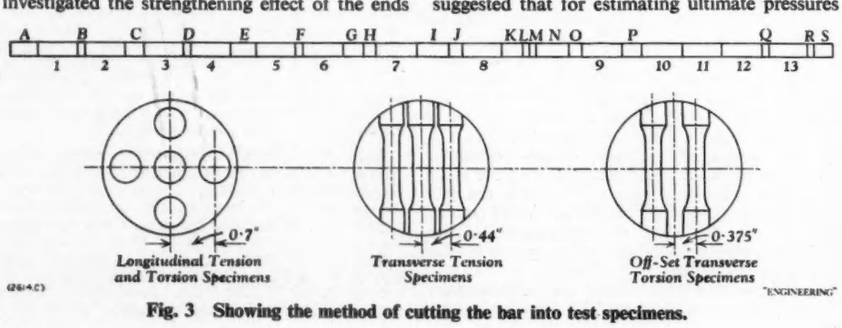
A B C D E F G H I J K L M N O P Q R S
1 2 3 4 5 6 7 8 9 10 11 12 13
0·7"
Longitudinal Tension and Torsion Specimens
0·44"
Transverse Tension Specimens
0·375"
Off-Set Transverse Torsion Specimens
(2614.C)
"ENGINEERING"

Fig. 3 Showing the method of cutting the bar into test specimens.

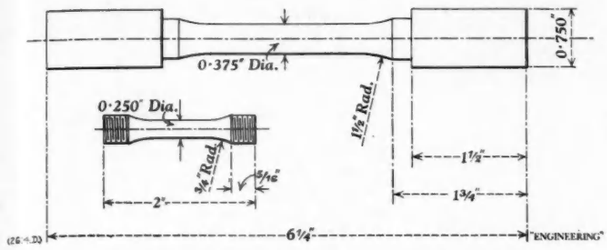

Fig. 4 Specimens used for the tension tests.

TEST SPECIMENS

The test specimens were machined from a 2-in. diameter bar of hot rolled steel in the as-rolled condition, given by the Park Gate Iron and Steel Company to the University of Bristol. Its percentage specification was C, 0·28; Si, 0·122; S, 0·033; P, 0·035; and Mn, 0·82. Finished specimens were normalised at 900 deg. C. under closely controlled conditions in the high-vacuum furnace described by Morrison,[7] and microscopic examination showed no signs of decarburisation.

Torsion tests indicated that the properties of the material varied across the cross-section. Accordingly, a transverse disc was cut from the bar and normalised. A sulphur print of this cross-section revealed no segregation, but considerable variation in hardness with radial position was found, as shown in Fig. 2. It will be noted that the bar is approximately 10 per cent. harder at between 0·6 in. and 0·8 in. radius than it is at the centre, and there is a corresponding variation in analysis and microstructure. At the centre the analysis was C, 0·28; P, 0·036; Mn, 0·76; and at 0·6 in. to 0·8 in. radius, C, 0·31; P, 0·039; Mn, 0·79. The soft skin of the bar, also revealed by the hardness test, was obviously caused by decarburisation during rolling, and the variation in hardness across the main part of the cross-section evidently arose from the ingot from which the bar was rolled.

The variation in composition and hardness is, of course, undesirable, but by careful positioning of the various specimens it was possible to allow for the difference in properties.

The bar was cut into sections for test specimens as shown in Fig. 3. From sections 1-13, thick-walled cylinders were machined. Torsion and tension specimens in the longitudinal and transverse directions and in positions through and off-set from the centre of the bar were machined from the intermediate sections A to S. Fig. 3 shows how these specimens were positioned in the bar cross-section. Table I gives the sizes of all the specimens tested.

The overall distribution of torsion and tension specimens was designed to give as complete a picture as possible of the properties of the bar material.

TENSION TESTS

Two sizes of specimen were used in the tension tests, one being small enough to allow offset transverse specimens to be cut from the 2-in. diameter bar. The dimensions of these specimens are shown in Fig. 4.

The tests were made in the machine designed by Professor Andrew Robertson and the late A. J. Newport, and described in *R. and M.* No. 1161. The load is applied by a screw driven through a double-reduction gear by an electric motor, and is measured by measuring the extension of a calibrated load bar placed in tandem with the specimen. Since the object of the tension tests was to measure the ultimate stress, no strain readings were taken.

Initially, a strain considerably greater than the strain at yield was applied to the specimen. After this, step strain increments were applied and the load measured five minutes after each increment. It had been found that equilibrium between strain and load was sensibly reached after this period. The test was continued until the maximum load was determined. For three specimens the strain was initially applied very slowly so that the plastic yield stress could be measured. After this the test was continued as above.

TORSION TESTS

Initially, several sizes of torsion specimens were tested (see Table I), but the stress/strain curves obtained were significantly different. This difference appeared to be unrelated to size effect and was probably due to the change of analysis across the bar cross-section already noted (see Fig. 2). It was decided, therefore, to standardise on a small specimen with ¼-in. dia. gauge length so that specimens could be cut in the longitudinal and transverse directions. This specimen was similar to the small one shown in Fig. 4, being 0·250 in. in diameter and 2 in. in overall length, but the gripping ends were each $\frac{7}{16}$ in. in diameter and $\frac{3}{8}$ in. long, with two longitudinal keyways diametrically opposite for transmitting the torque.

These standard specimens were tested in a small torsion machine designed by the late A. J. Newport of the University of Bristol and described by Morrison.[7] In this machine the specimen is twisted by a double worm reduction gear and the torque is measured by a calibrated torque bar in tandem with the specimen. The specimen is held in special grips at each end, which are designed to transmit only a pure torque to the specimen. For measuring strains, two clips were clamped to the specimen on a gauge length of $\frac{5}{8}$ in., as shown in Fig. 5. This gauge length was maintained accurately during clamping by a distance piece between the clips which was removed when they were firmly attached to the specimen. Each clip carries a mirror which is used with a scale and telescope for measuring fine strains, and a pointer which reads on a degree scale engraved on the movable head of the machine for measuring coarse strains.

The test procedure adopted was as follows. The specimen was strained continuously to the yield point and then step strain increments were applied up to failure. At each strain increment, measurements of torque and twist were made after a delay of five minutes to allow equilibrium between stress and strain to be sensibly established.

PRESSURE TESTS

The thick-walled cylinders were machined to the form shown in Fig. 6. Following Cook and Robertson the gauge length was made four times its external diameter. Special care was taken during machining to obtain concentricity of external and internal surfaces and to obtain a smooth bore. Fig. 7 shows a section of a cylinder assembled with the end fittings and connected to the high-pressure system. A photograph of the assembly is given in Fig. 8, which also shows the diametrically-opposite Martens-type extensometers which were used to measure the axial strain in the cylinders. For the preliminary ultimate pressure tests on cylinders 1, 3, 4, and 6, a high-pressure hand pump, capable of pressures up to 30 tons per square inch, was used. This pump[8] consists of a thick-walled cylinder fitted

TABLE I.—*Details of All Specimens Tested*

Symbol on length of bar	Specimens cut from length
A	Three offset longitudinal torsion specimens ¼ in., ¼ in. and ¼ in. diameter.
1	Test cylinder, K = 1·572.
B	One transverse standard ¼ in. dia. torsion specimen through centre of bar.
2	Test cylinder, K = 1·331.
C	Two offset longitudinal standard ¼ in. dia. torsion specimens.
3	Test cylinder, K = 1·998.
D	Not used.
4	Test cylinder, K = 2·290.
E	Three offset longitudinal torsion specimens ¼ in., ¼ in. and ¼ in. diameter.
5	Test cylinder, K = 2·660.
F	Not used.
6	Test cylinder, K = 1·775.
G	Four transverse standard ¼ in. dia. torsion specimens through centre of bar.
	One longitudinal standard ¼ in. dia. torsion specimen through centre of bar.
	Four offset longitudinal standard ¼ in. dia. torsion specimens.
H	Hardness check piece.
7	Test cylinder, K = 2·904.
I	Two offset longitudinal standard ¼ in. dia. torsion specimens.
	Two offset longitudinal standard ¼ in. dia. tension specimens.
J	Two offset transverse standard ¼ in. dia. torsion specimens.
8	Test Cylinder, K = 1·876.
K	Four transverse standard ¼ in. dia. torsion specimens through centre of bar.
	One longitudinal standard ¼ in. dia. torsion specimen through centre of bar.
	Four offset longitudinal standard ¼ in. dia. torsion specimens.
L	Not used.
M	One transverse standard ¼ in. dia. tension specimen through centre of bar.
N	Two offset longitudinal standard 0·357 in. dia. tension specimens.
O	One transverse standard ¼ in. dia. tension specimen through centre of bar.
9	Test cylinder, K = 2·482.
P	One transverse standard ¼ in. dia. tension specimen through centre of bar.
	Two offset longitudinal standard ¼ in. dia. torsion specimens.
	Two offset longitudinal standard ¼ in. dia. tension specimens.
	One longitudinal standard ¼ in. dia. torsion specimen through centre of bar.
10	Test cylinder, K = 3·179.
11	Test cylinder, K = 2·130.
12	Test cylinder, K = 3·602.
Q	Not used.
13	Test cylinder, K = 3·717.
R	Hardness check piece.
S	Four offset longitudinal standard ¼ in. dia. torsion specimens.
	One longitudinal standard ¼ in. dia. torsion specimen through centre of bar.

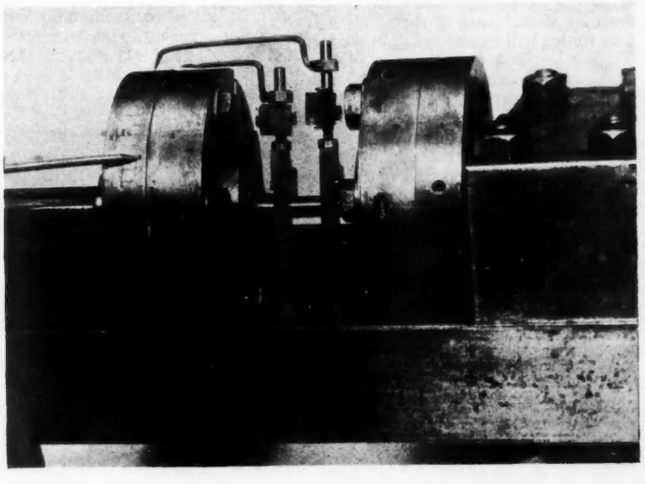

Fig. 5 Specimen set up in the torsion machine, showing the clips used for measuring strain.

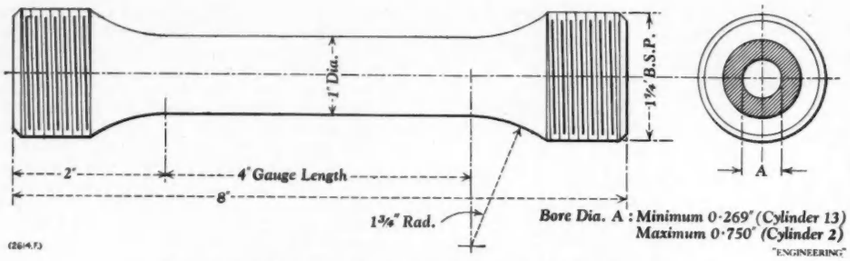

Fig. 6 Showing the form of the thick-walled cylinders tested.

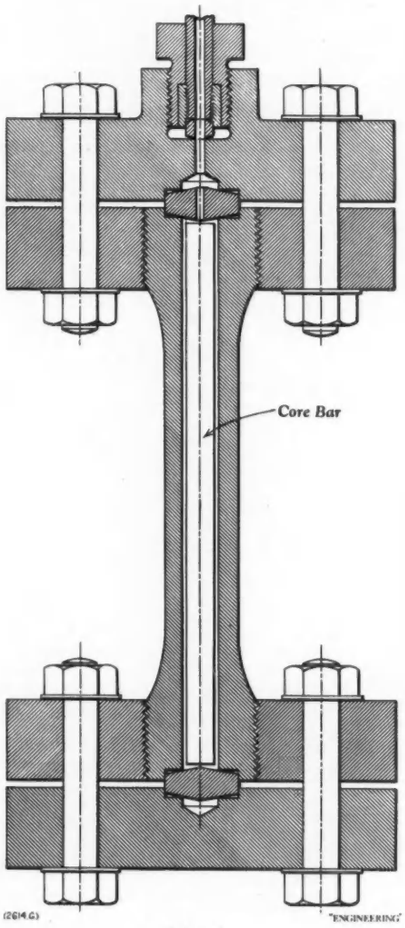

Fig. 7

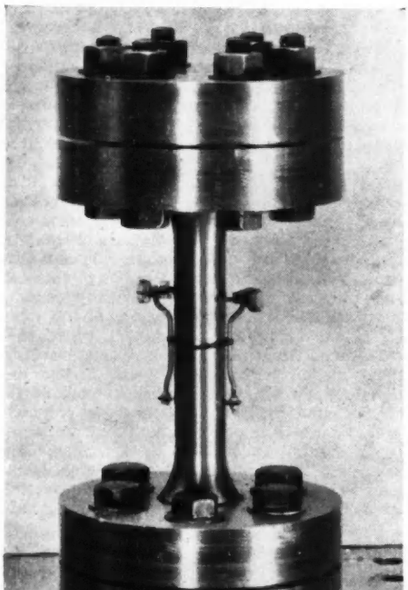

Fig. 8

Figs. 7 and 8 A thick-walled cylinder mounted in a rig for high-pressure testing, the right-hand illustration also showing the Martens-type axial extensometers.

with a 0·5-in. diameter ram and seal, the inlet and outlet ball valves being housed in a heavy T-piece screwed into the top of the cylinder. The ram is reciprocated by a hand lever to produce pressures up to 6 tons per square inch, and for higher pressures a 10-ton hydraulic jack is used to push the ram into the cylinder.

For testing the remaining cylinders a high-pressure rig was constructed which is capable of a pressure of 46 tons per square inch. This rig embodies an intensifier designed by Mr. W. R. D. Manning, of Imperial Chemical Industries, Limited, which is illustrated in Fig. 9. The high-pressure end of the intensifier consists of three component cylinders of En 25 steel shrunk together to form the high-pressure cylinder, the shrinkage fits being such that the cylinder remains elastic under the maximum pressure. Wave ring joints are used between the ends of the intensifier and the low-pressure and high-pressure cylinders, and leakage past the low-pressure and high-pressure pistons is prevented by Poulter-type seals,[9] i.e., by rubber sealing rings backed by metal members fitting closely in the bore. On the high-pressure piston the rubber sealing ring has a large pressure difference across it when maximum pressure is generated, and to prevent the rubber being forced out between the piston and cylinder, aluminium-bronze extrusion rings, such as those commonly used in liquid springing on aircraft undercarriages, are fitted. The ratio of areas of the high- and low-pressure pistons is such that a pressure of approximately 3 tons per square inch is needed on the low-pressure side to give a pressure of 46 tons per square inch from the high-pressure cylinder.

HIGH-PRESSURE RIG

The circuit diagram for the high-pressure rig is shown in Fig. 10. A C.A.V. injector pump is used to supply the low-pressure side of the intensifier and to charge the high-pressure cylinder. On the charging stroke of the intensifier, the low-pressure cylinder is connected to the reservoir by the change-over cock. The injector pump fills the high-pressure cylinder through the inlet ball valve, pushing the high-pressure and low-pressure pistons back and displacing oil from the low-pressure cylinder into the reservoir. During this stroke the high-pressure system is isolated from the intensifier by the outlet ball valve. On the delivery stroke of the intensifier the injector pump delivers to the low-pressure cylinder via the change-over cock and the inlet ball valve isolates the high-pressure cylinder from the pump.

It will be noted that the same fluid must be used in both the low-pressure and high-pressure systems, and as the high-pressure tubing is $\frac{1}{16}$-in. bore it was initially decided to use paraffin because its viscosity is still small at the maximum pressure used, though at a later stage a mixture of castor oil and Lockheed brake fluid was employed. The choice of paraffin did, however, give some difficulties in the change-over cock. This was initially in the form of a piston valve, but there was serious leakage past the piston and it was replaced by the ball-valve cock shown in Fig. 11. There are two ball valves in this cock and the change-over from delivery position (low-pressure cylinder connected to injector pump) to charging position (low-pressure cylinder connected to reservoir) is effected by forcing down the upper ball valve sufficiently hard to close the lower ball valve against the pump pressure.

The output from the high-pressure cylinder is connected by high-pressure tubing to two pressure gauges and the cylinder under test. One of the gauges is a Bourdon tube gauge reading up to 32 tons per square inch, and the other is a dead-weight piston gauge reading up to 46 tons per square inch. Both the Bourdon tube gauge and the piston and cylinder unit of the dead-weight gauge were supplied by the Budenberg Gauge Company. The weight carrier of the dead-weight gauge is continuously rotated by an eccentric drive similar to that described by Pearce.[10] Using these pressure gauges, the accuracy of the pressure readings was better than 1 per cent. In addition to these two gauges, a thick-walled cylinder fitted with a diametral extensometer was used to give accurate instantaneous readings of pressure up to 20 tons per sq. in. This cylinder had been calibrated against several standard gauges and was sensitive to 0·01 ton per sq. in., and accurate to better than 1 per cent.

Three high-pressure cocks were necessary, two to cut off the pressure gauges and the third to release pressure to the reservoir. These cocks were made to the design shown in Fig. 12, the outer ring being shrunk on to the body of the valve with sufficient interference to give elastic conditions at the maximum pressure. The

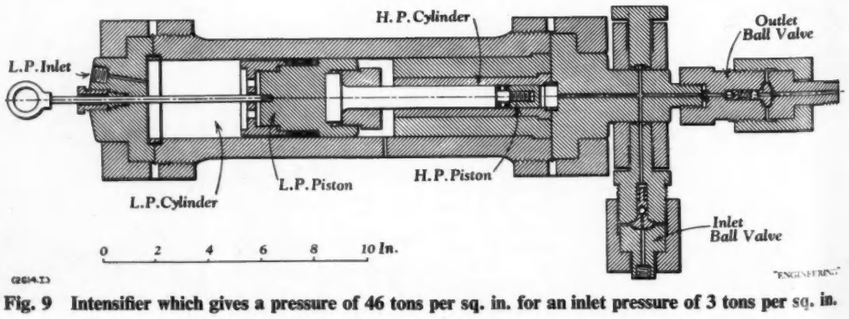

Fig. 9 Intensifier which gives a pressure of 46 tons per sq. in. for an inlet pressure of 3 tons per sq. in.

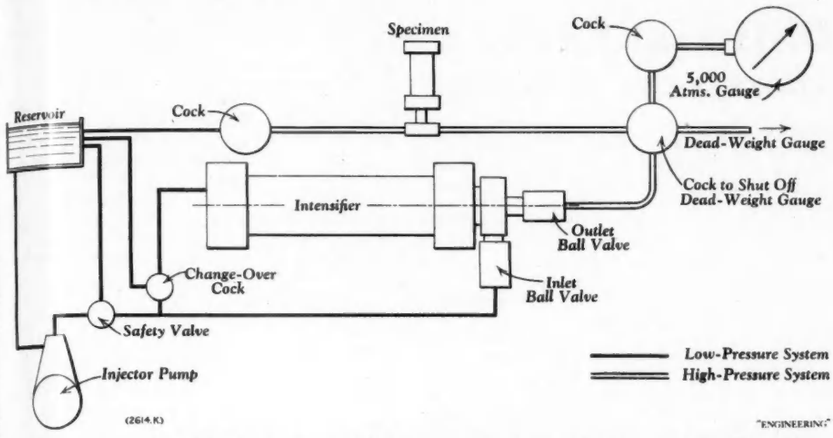

Fig. 10 Arrangement of the high-pressure rig (46 tons per sq. in.) used for testing thick-walled cylinders.

rubber glands used in the valve are again acting as Poulter seals, and it is not necessary to tighten them up hard to give satisfactory sealing. Extrusion rings are fitted in all positions where the rubber is subjected to a large pressure difference. The valve spindle and the gland ring through which it passes are both hone finished with a clearance between them of the order of 0·00005 in. These cocks have proved very satisfactory in service, no leakage having been observed, and they may be closed at maximum pressure without excessive effort.

All the high-pressure pipe connections are of the cone-ring type, similar to those adopted by I.C.I., Ltd., and larger cone rings were used in the joints to the test cylinder (see Fig. 7). The high-pressure tubing, $\frac{1}{16}$ in. bore and $\frac{3}{8}$ in. outside diameter, was drawn from high-chromium steel by Accles and Pollock, Limited. The high-pressure rig was mounted under a steel table and enclosed by steel plates.

PRESSURE-TEST PROCEDURE

The procedure adopted in testing the cylinders was as follows: The specimen was assembled with its end fittings as shown in Fig. 7, filled with oil and connected to the high-pressure rig, special care being taken to eliminate air from the high-pressure system. Two Martens-type axial extensometers were fitted to the specimen (Fig. 8), and the telescopes and illuminated scales were set up in conjunction with the mirrors on the extensometers. The pressure was then raised to approximately that required to initiate yield at the bore of the specimen. Then the pressure was increased in small steps. At each pressure increment, two factors tend to reduce the pressure with time: the cooling of the fluid after the initial compression, and the plastic straining of the cylinder. The initial drop in pressure was found to be measurable, so after three minutes the pressure was increased to the required value. A further five minutes were allowed for equilibrium between internal pressure and strain to be established, and then the external diameter of the specimen was measured by micrometer and the readings of the axial extensometers were noted. Measurements of the external diameter were made in directions at right-angles at the ends and centre of the gauge length of the cylinder.

At all pressures the specimen was surrounded by a heavy steel tube to prevent accidents, this tube being raised for measurements to be taken. After the ultimate pressure was reached, no further readings were taken, and the cylinder was burst while it was enclosed in the steel tube.

The second, concluding part of this article will be published in a subsequent issue. It gives the results of the tests and the authors' conclusions on the validity of the various equations for ultimate strength.

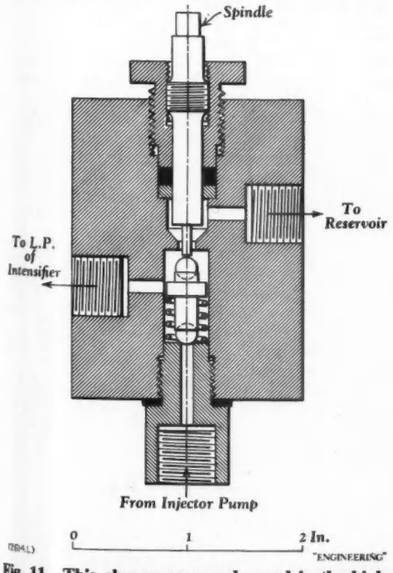

Fig. 11 This change-over cock, used in the high-pressure rig (Fig. 10), has been found to be useful and efficient for other hydraulic systems.

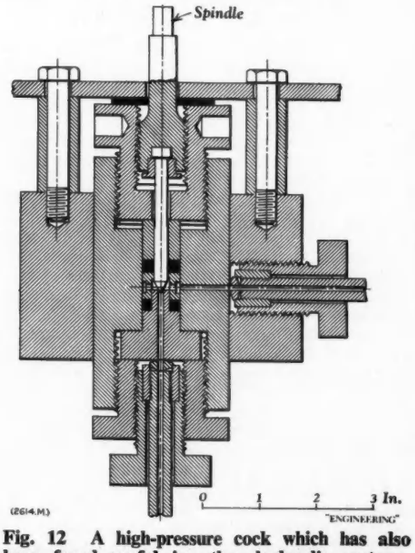

Fig. 12 A high-pressure cock which has also been found useful in other hydraulic systems. It can be closed at maximum pressure without excessive effort.

REFERENCES

[1] Cook, G., and Robertson, A. "The Strength of Thick Hollow Cylinders under Internal Pressure." ENGINEERING, vol. 92, page 786 (1911).

[2] Manning, W. R. D. "The Overstrain of Tubes by Internal Pressure." ENGINEERING, vol. 159, pages 101 and 183 (1945). See also letters pages 356 and 435.

[3] Blair, J. S. "Stresses in Tubes due to Internal Pressure." ENGINEERING, vol. 170, page 218 (1950). See also Letters on pages 383, 412, 476 and 508.

[4] Faupel, J. H., and Furbeck, A. R. "Influence of Residual Stress on Behaviour of Thick-wall Closed-end Cylinders." *Trans. A.S.M.E.*, vol. 75, No. 3, page 345 (1953).

[5] Deffet, L., and Gelbgras, J. "Le compartement des Tubes a Parois Epaisses Soumis a des Pressions Élevées." *Revue Universelle Des Mines*, 9th Series, vol. 9, No. 10, page 725 (1953).

[6] Van Iterson, F. K. Th. *Plasticity in Engineering*, London, 1947.

[7] Morrison, J. L. M. "The Yield of Mild Steel, with Particular Reference to the Effect of Size of Specimen." *Proc.I.Mech.E.*, vol. 142, page 193 (1940).

[8] Crossland, B. "The Effect of Fluid Pressure on the Shear Properties of Metals", *Proc. I. Mech. E.*, vol. 168 (1954).

[9] Poulter, T. C. "Apparatus for Optical Studies at High Pressure." *Physical Review*, vol. 40, page 860 (1932).

[10] Pearce, J. F. "A Modified Budenberg Balance." *Journal of Scientific Instruments*, vol. 29, No. 1, page 18 (1952).

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PUBLIC HEALTH AND INDUSTRY

Mr. Calvert's Address

As the last duty of his year of office as President of the Institution of Sanitary Engineers, and before inducting his successor on Tuesday, January 11, Mr. E. H. Vick, M.I.C.E., presented the Gold Medal of the Institution to Mr. David M. Watson, past-President, and now President of the Institution of Civil Engineers. Mr. Watson was President of the Institution in 1939 and the three following years during the early part of the War: the medal has been inscribed with "For Services to Sanitary Engineering and to the Institution of Sanitary Engineers," and marks his great contributions to that particular branch of engineering.

The new President is Mr. J. T. Calvert, M.A., B.Sc. (Oxon.), M.I.C.E., F.R.I.C., a partner in the firm of John Taylor and Sons, Artillery-row, Westminster, London, S.W.1. During the course of his address Mr. Calvert referred to the need for fundamental research in many of the problems associated with sewage disposal; in particular, he referred to the lack of measurements made on the absorption properties of filter media such as, for example, smooth river stones and very porous gravel, so that it was not possible to compare accurately the merits of these two media.

Discussing the form of the conditions of contract to be used, particularly in the case of sea outfalls where the uncertainties of construction were considerable, Mr. Calvert expressed his preference for "target-price" contracts where the contractor received a fixed sum plus a fee together with a proportion of the saving he had effected on the target price. Such an arrangement encouraged economy and had proved "very satisfactory where tendering was mainly guesswork."

Referring to river pollution, the new President suggested that it was neither practicable nor desirable to seek "perfectly-pure water at any cost." Apart from the considerable difficulty of defining "perfectly pure," the cost would be prohibitive and would place a severe burden on industry if attempts were made to treat effluents until rivers were absolutely unharmed by the discharge.

Finally, the hope was expressed by Mr. Calvert and Mr. Vick that, during the coming year, the change of name of the Institution to the Institution of Public Health would be finally effected, when it would more accurately represent the activities of the members who contributed so much to the general health of the community.

DESIGN IN ONE PIECE

FRESH APPROACH WITH LOW-PRESSURE PLASTICS

Plastics are sometimes thought of as substitutes for metals. While it is true that they have been used to replace metals in some applications, plastics have properties of their own which designers must consider carefully and intelligently if they are to take the fullest advantage of these new materials. A development since the war has been the use of glass fibre and asbestos-reinforced plastics which can be moulded at low pressures. With these plastics much larger moulds can be used than with conventional plastics; an example of this technique is the hull of a 45-ft. boat which has been made from glass-reinforced plastics in a single mould. If the designer has to make only one item instead of a large number of items which must later be brought together, it is clear that the design problem is an entirely new one. This aspect of the use of plastics was discussed by Dr. N. J. L. Megson, D.Sc., F.R.I.C., F.P.I., in a paper entitled " Non-metallic new materials in Engineering," read before the Institute of Marine Engineers on January 11, 1955.

GLASS-FIBRE REINFORCEMENT

Dr. Megson began with a general account of the types of plastics that have been developed. In their original form plastics were amorphous, resin-like substances having only little mechanical strength, and for most applications they needed a reinforcing filler. Fillers that had been used were wood-flour, cotton linters, rag, chopped string, asbestos, and glass fibre. Before the last war the resins available were such that it was necessary to drive off the water vapour evolved in moulding by using high pressures. Because of the high pressure needed it was not economical to make the presses that would be required for large mouldings. During the war the polyester or " contact " resins were developed on a large scale in America. They differed from the high pressure resins in that they could be heat- or catalyst-cured at low pressure, because they evolved no volatile products, such as water, during cure. It was realised that any reinforcing filler for the polyester resins should be as strong as possible, and glass fibre was chosen partly for its strength and partly because it was available in production quantities. Glass had no tendency to absorb water, which was so striking a characteristic of cotton or paper, and which caused dimensional instability in service.

In this country it had not been possible to develop the glass/polyester resin plastics during the war owing to lack of both the resins and the glass fibre in sufficient quantity. In 1945, however, a new material known as Durestos was produced; it was an asbestos felt impregnated with a thermo-setting phenolic resin. It was supplied in sheets of 8 ft. by 4 ft. and seemed promising for the moulding of large forms. Although the phenolic resin evolved water during cure, moulds were designed with a porous backing through which water vapour could be drawn off; it was found possible to mould with pressures varying from 150 lb. per square inch to " no-pressure," when only hand or roller pressure was needed. One of the largest products made from Durestos was a 14-ft. diameter radar reflector.

Whether glass/polyester or asbestos/phenolic resin materials were used, the moulds could be made of very cheap materials, such as wood or concrete, requiring little skilled labour for their production. In this respect the moulds compared favourably in cost and ease of production with the highly expensive steel dies necessary for conventional plastic moulding. It followed that one could contemplate the making of large items in comparatively small numbers, whereas in the past the emphasis has been on small items in large quantities.

There were a number of ways in which glass reinforced plastic or Durestos could be moulded; by using suitable temperatures for curing and suitable types of resin, forms could be shaped between matching moulds, or the pressure could be applied to the form through the medium of a rubber bag; for both glass- and asbestos-reinforced plastic it was possible to use hand pressure, building the plastic up round a suitably shaped mould. In all cases there would be definite requirements for the type of resin used and the heat applied to the mould.

Although there were details of the properties of plastics, it had to be emphasised that the use of strength data was not so straightforward as in the case of metals. Long experience of metal parts and their strength and general mechanical properties gave an engineer confidence in designing structures with appropriate safety factors. Plastics differed from metals because structures were built from them in an entirely different way. Moulding processes, which could avoid the use of joints and rivets, replaced the " Meccano " method of construction, and therefore the whole question of design, involving stress concentrations, stiffness and so on, could be approached in a revolutionary way. Dr. Megson gave tables of physical properties which showed that in most respects reinforced plastics were inferior to metals, and said it seemed strange on that account that they should be used at all. He then quoted from a paper by Lorne Welch in " Glass Reinforced Plastics "*: " The outstanding advantage which the designer of reinforced plastics has is the ability to design things which are conceived and built as a whole, of a shape which is dictated by the requirements of the job and not by the necessity of using standard gauges and sections . . . . The correct approach is to consider what are the real requirements and loads upon the structure, and then to evolve the simplest possible shape and structure to suit them. The result may look very different from the original, but since the properties of the material and the methods of working it are so dissimilar to previous materials, this is not surprising." It was this idea of designing a structure as a whole that was so important when using plastics. It would be possible to mould items with variable wall thicknesses to suit anticipated loads; the edge of a panel could be thickened to provide increased stiffness or to allow the introduction of a bolted joint; in a beam, the thickness of tension and compression members could be modified to accommodate the bending moment.

JOINTLESS CONSTRUCTION

The advantages of structural plastics were: the low pressures employed in moulding allowed the use of cheap moulds and moulding equipment; low specific gravities permitted greater skin thicknesses (as compared with metal) without undue weight penalty; the increased thickness implied in turn that machining and finishing operations caused less tendency to structural damage; surfaces could be perfectly smooth and of any shape, and the number o joints could be small; the materials were resistant to corrosion; sandwich structures could easily be made, so that stabilised skins were readily available; variable thicknesses and local reinforcements were easy to produce.

The disadvantages were: high cost; materials were best suited for diffuse loadings, stress concentrations being objectionable; elongation at break was low, and compared with metals toughness was low; temperature resistance of materials based on polyester resins is low.

A number of large structures had been made from glass- or asbestos-reinforced plastics. The most ambitious moulding yet made in this country was probably the hull of the 45-ft. launch; plastics car bodies had been made by a number of firms, and in America the plastics car body was very popular. These large mouldings had not had time to prove themselves in use; the progress of the plastics industry was assured, but it might have to be slow if reliable products were ultimately to be put on the market. New materials were being evolved, both basic resins and various reinforcements. Production difficulties would have to be overcome, because each component made by low pressure moulding presented its own problems. Long experience of the new techniques was probably the best guide to solving the difficulties; it could only be obtained the hard way.

* *Glass Reinforced Plastics*. Edited by Phillip Morgan. Published for " British Plastics " by Iliffe and Sons, Limited, Dorset House, Stamford-street, London, S.E.1.

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TURBINE-DRIVEN AUXILIARY POWER UNIT FOR AIRCRAFT

Solar 'Mars' Completes 500 Hours

The turbine-driven auxiliary power unit installed in the Douglas C-124C Globemaster transport aircraft in service with the United States Air Force has recently completed 500 hours of satisfactory service. The power unit comprises a 14-kW auxiliary generator set powered by a Mars gas turbine constructed by the Solar Aircraft Company, San Diego, U.S.A., and is intended to provide auxiliary power as required either during flight or on the ground.

During its 500 hours of service, the generator was virtually in constant operation during training flights. After its return to the Solar works for overhaul, the company have issued a report on the results of the inspection. A check calibration of the generator set before overhaul showed less than 2 per cent. change in the fuel consumption/horse-power and turbine-inlet temperature/horse-power relationships.

In the Mars engine, the turbine is of the radial inflow type with the rotor in forged Timken 16-25-6 alloy. A dye-penetrant inspection of the rotor revealed no cracks at all. The " growth " in rotor diameter amounted to only 0·0008 in., and no appreciable change in hardness was found. Nevertheless, pending further operating experience, it was decided not to recommend the component for re-use.

Most of the other " hot " parts were found to be in equally good condition. Part of the turbine scroll showed minor thinning in local areas due to flame impingement, but this never exceeded 0·004 in. in the 0·032-in. material. The wear caused no loss of efficiency.

The turbine nozzle area was found to have increased by 0·25 per cent., probably due to the scrubbing action of the hot gases from the combustion chamber. This expansion contributed to the development of slight gaps—maximum 0·012 in.—at the trailing edges of the nozzle vanes. This was within the specified tolerances, and the nozzle was still serviceable after vapour-blast cleaning. Only the burner and the silicon-impregnated glass-fibre bellows connecting the compressor to the combustion chamber showed unacceptable deterioration.

The rotating parts, including the impeller and bearing assemblies which operate at 36,000 r.p.m., were found to be free from flaws. The aluminium-alloy impeller had decreased by 0·0005 in., probably due to scouring by foreign parts and, although acceptable, the unit was not recommended for re-use.

Ball and roller bearings, reduction gearing, and major engine accessories, although showing normal wear, were still serviceable. The stainless-steel housing enclosing the generator set, however, showed extensive wear, and some of the smaller accessories had deteriorated and required replacement.

The satisfactory condition of the principal components is attributed to the low design turbine-inlet temperature (1,100 deg. F. at rated output in standard atmosphere) and to the fact that the Mars gas turbine was designed for simplicity and reliability.

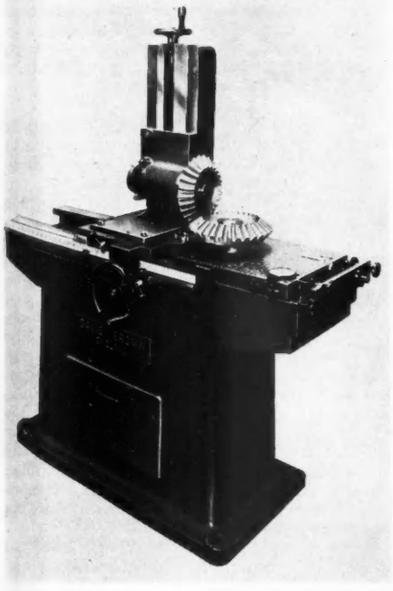
CHECKING THE ACCURACY OF GEARS

SPUR AND HELICAL GEARS, BEVELS AND WORMS TESTED ON THE SAME MACHINE

The machine shown in the accompanying illustrations is the first of a range to be made by the David Brown Tool Company, Huddersfield, for checking concentricity, tooth contact, centre distance and tooth thickness of internal and external spur and helical gears. The present machine will accommodate spur gears up to 24 in. in diameter, and extra fittings are available to deal with shaft gears up to 10 in. in diameter, worms of the same maximum size, and bevels, of both the straight and spiral types.

TESTING BY ROLLING CONTACT

The machine operates by rolling gears together in pairs, one gear being mounted on a floating carriage and the other on a carriage which is adjustable to suit various sizes of gear, and is locked in position during testing.



Extra fittings can be supplied for testing bevel gears, as shown here, shaft gears or worms.

The two carriages are mounted on a bed of ribbed construction, which is designed for maximum rigidity. Referring to the diagram, the adjustable carriage *a* is moved by a handwheel through a rack and pinion. This carriage is located by two slideways, one of V-section and the other rectangular, and can be locked in any required position along the bed. It has a machined surface for mounting the extra attachments for bevel and worm gears, and has a No. 4 Morse taper for an arbor which carries the spur gears.

The sensitive carriage *b* is located on four steel balls running in hardened and ground guide-ways to give freedom of movement and maximum sensitivity. The gear to be tested is carried on an arbor in the same way as on the other carriage. The sensitive carriage operates against spring pressure, which can be adjusted by means of the screw *c*. Spring pressure can be exerted in either direction, to suit internal or external gears, and an indictaor *d* is fitted to show in which direction the spring is acting. A dial indicator, which is sensitive to 0·0005 in., shows the movement of the carriage due to gear inaccuracies. It can be set to zero by rotating the dial, and adjusted by the screw *e*. If the gear being tested is so large that it covers the whole of the sensitive carriage, the dial indicator can be removed and placed in the auxiliary bracket *f*; adjustment is then made by the screw *g*. A safety screw *h* prevents the sensitive carriage from over-running, and so protects the dial indicator. A graduated scale *j* is attached to the sensitive carriage, and there is a Vernier on the adjustable carriage, to enable the centre distance to be read directly when the gears are in position.

INDIVIDUAL OR ROUTINE TESTING

In operation the two gears are mounted on their arbors on the carriages, the lighter one being placed on the sensitive carriage in order to ensure freedom of movement and minimise wear. The adjustable carriage is then moved along the bed to bring the gears into mesh, and is clamped in such a position that it exerts a slight spring pressure on the sensitive carriage. The gears are then rotated and any variation in tooth thickness or concentricity is registered on the dial indicator. The centre distance is read from the Vernier scale, and backlash can be calculated from the difference between the working centre distance and the centre distance when the gears are in metal-to-metal contact.

For batch inspection, or checking a number of gears against a master gear of known accuracy, a stop is provided on the bed so that the adjustable carriage can be returned to the same position after checking each gear.

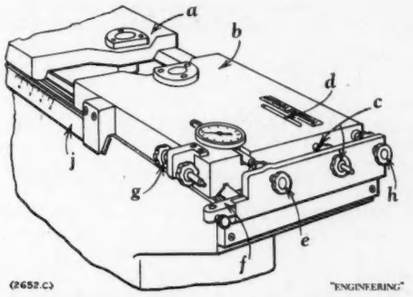
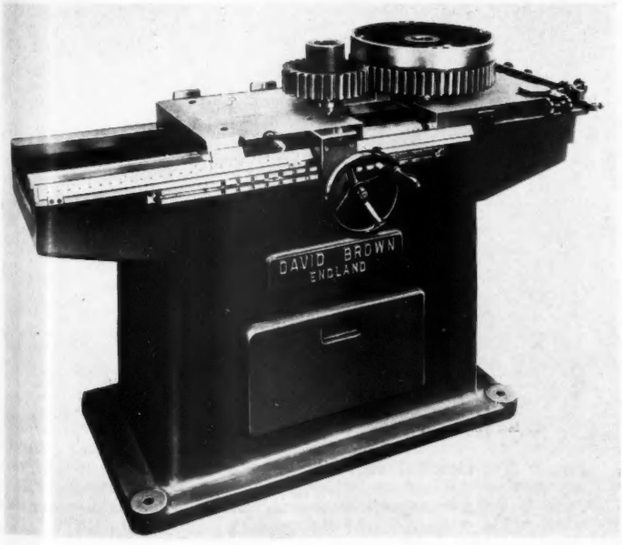


Diagram of the sensitive carriage showing adjustment points, dial gauge and centre-distance scale.



The David Brown gear tester operates by rolling a pair of gears together, one gear being on a sensitive carriage which records inaccuracies by means of a dial gauge.

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SPARKING PLUGS

Overhead Earth Wire for Sleeve-Valve Engines

K.L.G. Sparking Plugs, Limited, Putney Vale, London, S.W.15, in conjunction with the Bristol Aeroplane Company, Limited, have designed a new sparking plug for use on Bristol sleeve-valve engines. It incorporates an overhead earth wire replacing the more orthodox arrangement of "side-fire" earth wires used in plugs having precious-metal electrodes.

One of the principal reasons why side wires have been favoured for piston engines is that the spark is not screened by the earth wire and the ignition of the mixture is normally more effective. By experiment, the K.L.G. Company have found that if the body of the plug at the combustion chamber end is machined in a bell-mouth form, the utmost use can be made of the excellent swirl characteristics in the cylinder of the sleeve-valve engine. This results in an induced circulation of the mixture within the plug mouth and makes the overhead gap fully effective by removing any screening effect which would otherwise be expected.

The use of unequal electrode dimensions has also increased gap stability while providing a partial "side-fire" effect. In this arrangement the diameter of the central electrode is larger than the dimension of the earth wire.

Smiths Aircraft Instruments, Limited, Cricklewood, London, N.W.2, are the sole sales concessonaires for K.L.G. spark plugs.

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REFINERY CONSTRUCTION FILM

A black-and-white film, the "Story of Coryton," has been produced by Verity Films, Limited, for the Vacuum Oil Company, Limited, Caxton House, Westminster, London, S.W.1. The film (16 mm.) runs for about 30 minutes and is a non-technical documentary describing the building of the refinery from the clearing of the land to the final opening by Her Majesty Queen Elizabeth, the Queen Mother. The photography is excellent and there are shots of the tidal flooding which occurred in February, 1953. The commentary is also very good. Copies of the film are available on loan from The Film Library, Sound Services, Limited, 269 Kingston-road, London, S.W.19. A full description of the refinery and its construction were given in ENGINEERING, vol. 177, page 687 (1954).

TESTING GAS-TURBINE FUEL SYSTEMS

COMPONENT TEST RIGS AND INSTALLATIONS

The opportunity occurred recently to visit the production-testing facilities at Joseph Lucas (Gas Turbine Equipment), Limited, Birmingham, where components of gas-turbine fuel systems such as fuel-flow control units, burners and flow distributors, and complete fuel pumps are tested and calibrated during and after assembly.

All such components are manufactured to extremely close tolerances and are subjected to rigorous inspection at each stage of manufacture, before each individual sub-assembly is calibrated in the main test house. The latter is known as the "paraffin test house," since the tests here are carried out on kerosene fuel. In addition to the paraffin test house, two separate test houses have been in operation during the last four years in which certain complete fuel pumps are endurance-tested running on petrol. The necessity for this procedure has arisen with the general adoption of wide-cut gasoline fuels for military gas turbines as an alternative to kerosene.

FUEL PUMPS AND FLOW CONTROL

Before describing some typical test rigs it is desirable to summarise very briefly the range of fuel-system components under consideration. Lucas gas-turbine fuel pumps are at present made in five sizes, all operating at a maximum delivery pressure of 2,000 lb. per square inch, and ranging in available capacity at the rated speed from 438 gallons per hour (at 4,000 r.p.m.) to 3,000 gallons per hour (at 3,000 r.p.m.). This latter is on a dual-pump unit, the largest single pump having a capacity of 1,500 gallons per hour at 3,000 r.p.m.

The pumps are all of the variable-stroke piston type, comprising a number of spring-loaded pistons working in bores inclined relative to the rotor axis, and in contact at their outer ends with an inclined cam-plate. The incidence of this is adjusted by a servo mechanism to vary the piston stroke as required to give the desired fuel flow, which depends on engine speed (selected by the pilot's throttle valve), altitude, and other flying conditions. Compensation for the effects of varying air density is made by an altitude control unit, and for the effects of rapid acceleration by a fuel/air-ratio over-ride unit, which operate the cam-plate servo-piston. In the event of overspeeding, a built-in speed governor in the pump also acts on the cam-plate servo-piston to reduce the pump stroke. The speed governors are either of the centrifugal fuel-pressure type or of the hydro-mechanical pattern giving a fluid pressure which is a direct function of speed and which is used for operating speed-governed and other control systems. To overcome the difficulties encountered in the former type due to the variation of fuel pressure with density, a density-compensating mechanism has been evolved.

In early jet engines still in service, altitude compensation is by "barometric pressure control" in which the pump delivery is regulated by the nacelle pressure, i.e., the pressure at the engine compressor intake. A separate throttle valve gives the pilot control over the fuel supply to vary the engine speed. Many propeller turbines now in service are fitted with "flow-control" units in which are grouped the pilot-operated throttle valve, high-pressure shut-off cock, or low-pressure filter and the altitude-responsive unit itself. The latter controls the fuel flow, through the pump servo-system, in response to the pressure drop across the fuel throttle valve and to the engine nacelle pressure. This has the advantage, compared with the barometric pressure control, that the pump pressure at part-throttle openings is reduced and the life of the pump is thereby increased.

For higher-altitude engines, full-range flow control units, also incorporating the pilot's throttle valve and a variable automatic flow orifice, are employed. In these the fuel flow is regulated according to the pressure drop across the entire fuel-flow unit and the nacelle air pressure. Units of this type are suitable for use up to 60,000 ft. A more advanced altitude-compensation unit is the proportional flow control, which offers advantages in operation and installation, and can be readily combined in a single unit with speed-governing, jet-pipe temperature over-ride and acceleration over-ride controls.

These units, together with centrifugal pumps, both air and mechanically driven, and burners, and metering flow distributors, constitute the main products of the fuel-system side of the Lucas gas-turbine division.

PETROL TEST HOUSES

Turning now to the test installations, the two petrol test houses contain both 50-h.p. rigs and 150-h.p. rigs, the latter for calibrating the largest dual fuel pumps and testing the efficiency of speed governing, and the 50-h.p. rigs for dealing with all the smaller types of fuel pump. Essentially the test houses are designed and constructed on similar lines, and it is proposed to consider here the 50-h.p. installations.

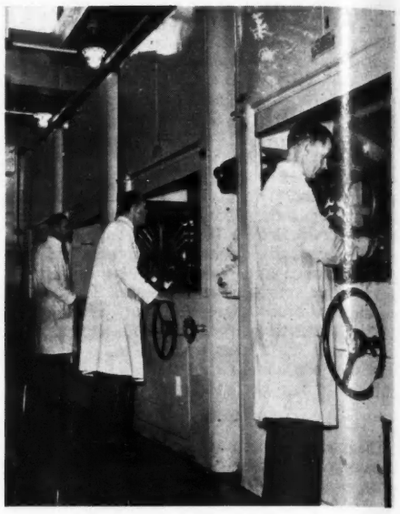

Fig. 1 The operating area of the petrol test house in which Lucas gas-turbine fuel-pumps are endurance tested on petrol. A drop shutter falls automatically, cutting off the rig completely, in the event of fire.

Fire precautions have been a primary factor in the layout of the petrol test house, which is divided into three sections. In the operating area, housing the component under test, the rig controls and instruments, and the test observers, there are no electrical installations other than flameproof lighting and a flameproof limit switch forming part of the fire-protection system. The rig-mechanism section, also free from electrical plant, houses the back of the test rigs with the driving gear; the electrical switchgear and motor section are completely separate. All bare metal parts in the rig rooms are earthed, and fuel vapour is removed through a comprehensive venting system supplied by an extractor fan on the test house roof.

In the operating area, Fig. 1, the front part of each rig, containing the instrument panel and the driving head, is surrounded by a sheet-metal booth provided with a drop shutter arranged to fall and cut off the rig completely

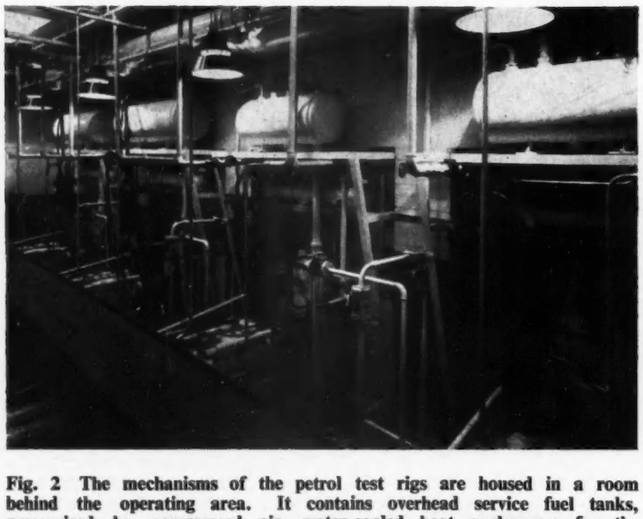

Fig. 2 The mechanisms of the petrol test rigs are housed in a room behind the operating area. It contains overhead service fuel tanks, pressurised by compressed air, water-cooled heat exchangers for the circulating fuel, and pump and motor units driving the rig head.

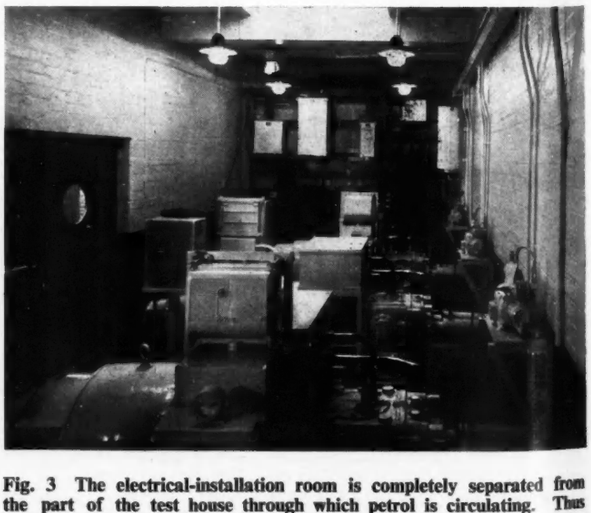

Fig. 3 The electrical-installation room is completely separated from the part of the test house through which petrol is circulating. Thus there is no necessity for flameproof motors, etc. Autosynchronous 50-h.p. motors drive the hydraulic pump/motor units.

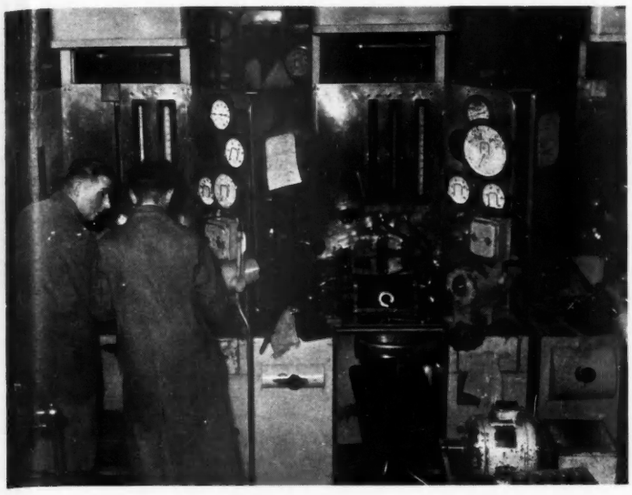

Fig. 4 General view of paraffin test house, where sub-assemblies and complete units are calibrated and endurance tested.

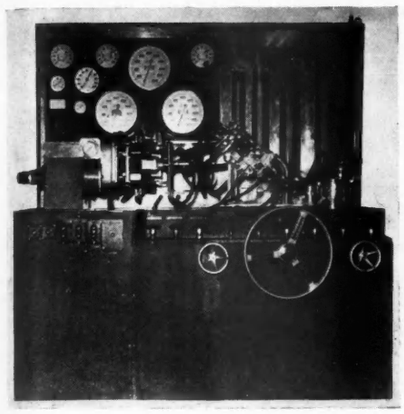

Fig. 5 Flow-control unit calibration rig, with built-in variable atmosphere control and provision for automatic cycling.

in the event of fire. Two fusible links are provided in the suspension system of each shutter, one in the operating section and one in the rig-mechanism room. Should any one of these links fuse, the shutter will descend and thereby make an electric contact thus completing the circuit of a solenoid-operated air valve. The latter then automatically opens a fuel dump valve allowing all the fuel in the rig circuits to escape to underground fuel tanks; it also opens the main electrical circuit breaker and actuates the fire-extinguishing system, releasing liquid carbon dioxide through sprinklers distributed throughout the test building. With these precautions, therefore, the test observers have only to leave by the exit specially provided.

The room housing the rig mechanisms (Fig. 2) contains overhead service fuel tanks for supplying the component under test, each of these tanks being replenished from an underground storage tank. The latter is in turn supplied from the main works storage tank.

Each service tank is pressurised by an air supply from a small compressor unit in each test house, the air pressure being regulated by a reducing valve on the rig panel. The fuel passes from the service tank through the rig flow meters and two filters, (a large unit to separate the larger impurities and a Micronic unit which removes residues above 2-3 microns) and thence to the inlet of the pump under test. The pump delivery passes by way of a throttle valve through manually-controlled water-cooler units in the rig-mechanism room and back to the overhead tank. Fuel is thus recirculated at a constant temperature unless it becomes contaminated when it is changed. Cooling water for the heat exchangers of the petrol test houses is supplied from an external intercooler.

Also in the rig-mechanism room are variable-delivery hydraulic pump and motor units providing an infinitely-variable-speed drive through a step-up gearbox to the driving head mounted on the front of the rig. The maximum speed of the driving head is 5,000 r.p.m.

Auto-synchronous 50-h.p. electric motors located in the electrical installation room (Fig. 3) provide the drive for the hydraulic pump/motor units, and in this room also are located all switchgear and fuses, and electrically operated temperature recorders. The complete isolation of all the moving electrical equipment has made it unnecessary to resort to flameproof units, with a consequent wider choice and, it is considered by the company, greater security against fire and explosion hazard.

THE PARAFFIN TEST HOUSE

A large number of test rigs are located in the paraffin test house (Fig. 4) where both sub-assemblies and complete units are calibrated and endurance-tested. Leak tests are carried out by subjecting the components, immersed in a fluid tank, to air pressure. To check that the static torque of closely-toleranced sleeve-and-plug assemblies is not outside the specified value at low temperatures, a refrigerator is provided to cool the part down to — 40 deg. C. Dynamic testing at low temperatures is not, however, part of the production-test programme.

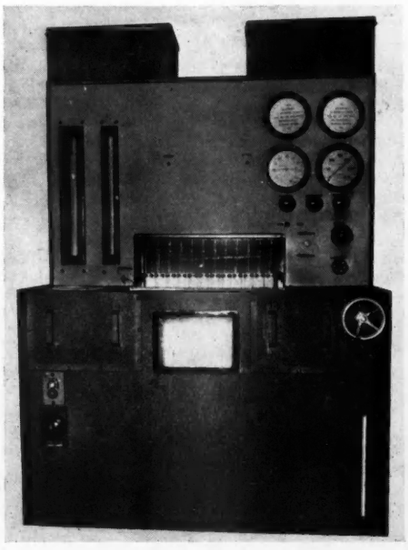

Fig. 6 Burner calibration test rig, which provides also for checking the angle of the spray cone and the uniformity of fuel distribution.

Most of the calibrating test rigs, which range from 5-h.p. to 100-h.p. capacities are constructed on the same general lines. In some rigs the driving head is driven, as in the petrol pump-test rigs, by variable-delivery hydraulic pump and motor units, whereas in others a variable-speed electric motor is employed.

A typical rig for calibrating flow-control units is illustrated in Fig. 5. On the driving head in front of the rig is mounted a G.T.D. slave pump, driven by a 100-h.p. electric motor through a variable-speed gear and a step-up gearbox. Fuel from a built-in kerosene fuel tank is supplied by a booster pump, through the fuel flowmeters on the face of the rig, to the slave pump which feeds the unit under test. The fuel flow is measured at various fuel pressures (controlled manually by a throttle valve) over the whole range of altitude and engine conditions, a compressor/vacuum-pump unit providing a variable atmosphere on the barometric capsule of the flow control unit to simulate altitude conditions. The fuel delivered from the unit is returned through a water-cooled heat exchanger back to the tank. Automatic cycling gear is provided for endurance-functioning tests. For testing the solenoid-operated controls with which some units are equipped, a rectified 24-volt direct-current electrical system is provided.

Burners, in addition to being calibrated and adjusted as necessary, are examined on a visual rig to verify the angle of the spray cone and are also checked for uniformity, i.e., to ensure that the fuel flow is equally distributed around the spray cone. Although within the Lucas test department these three checks are performed generally on separate rigs, a single combined burner calibration test rig has been devised by the company and is illustrated in Fig. 6. Here, the slave fuel pump supplying the burner is driven by a 10-h.p. electric motor and is supplied from two header tanks through a heat-exchanger unit, the header tanks being supplied by a booster pump from a storage tank. The usual fuel pressure and flow gauges are provided.

Other specially-developed test rigs exist for calibrating flow distributors, barometric pressure and fuel/air ratio control units, etc. It should be mentioned that all the test rigs mentioned in this article are available commercially and are designed for operating from a 400/440-volt three-phase 50-cycle supply, though they have also been supplied to suit local conditions. Cooling-water supplies are required and, while some of the test rigs are provided with their own air compressors, others need external air supplies.

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STATISTICAL METHODS IN INDUSTRY

New Journal of Abstracts

A journal of abstracts of published papers and articles on statistical methods, the second copy of which has recently been received, has been issued by the International Statistical Institute, 2 Oostduinlaan, The Hague, Netherlands. It is entitled *International Journal of Abstracts on Statistical Methods in Industry*, and will be published three times yearly.

The abstracts are classified under the following subject headings: Process Control; Sampling and Acceptance Inspection; Research and Development; Administrative Applications and Operations Research; and Management Applications. They are printed on stiff paper with plain backs, three to a page, so that they may be cut out to form cards of identical size and used as a card index. They are numbered consecutively, and it is proposed to include a classified index with the last issue of each volume.

Copies of the journal may be obtained from the International Statistical Institute at an annual subscription of 18*s*. Single copies are supplied at a cost of 7*s*. 3*d*.

Honeycomb core block, built up from corrugated aluminium foil 0·003 in. thick, to which sandwich skins are subsequently bonded. This form of construction combines strength with lightness.

HONEYCOMB SANDWICH CONSTRUCTION IN ALUMINIUM ALLOY

Some general particulars have been released on the method of honeycomb sandwich construction for aircraft primary structures developed by A. V. Roe and Company, Limited, Greengate, Middleton, Manchester, examples of which were shown at the Society of British Aircraft Constructors' display last September.

The Avro lightweight sandwich construction, which can be formed into almost any desired single or double curvature, consists of a hexagonal honeycomb of aluminium foil 0·003 in. thick bonded between metal sheets, resulting in an exceptionally stiff and light structural material, and giving a smooth external contour free from " waviness." It is stated that a square foot of honeycomb core, 1-in. thick, weighs only 4 oz., and it is possible to save up to 30 per cent. in weight on a component designed for construction in the new material.

To make the honeycomb core, a coil of thin aluminium foil is prepared chemically and coated with the bonding medium, Catalin, a hot-setting adhesive resin. The foil is then passed between rollers which form corrugations in it, and pieces of constant length are cut off automatically.

The core is then formed in a core-making machine which has a series of fixed metal pegs protruding from the back. The length of foil is placed so that the crests are lying on the pegs; an identical piece is placed on top so that the troughs of the second piece are on top of the crests of the first, the edges being aligned with great care. The strips are then bonded by heat and pressure from a series of heated pegs. The assembled piece is then moved down, and a third piece is added, and so on, until a core block of the required size has been built up. This process is manually controlled, but a new completely-automatic core-building machine is at present being constructed.

The honeycomb core is then assembled on the outer skin panel, which has been coated with resin and clamped to a specially-designed fixture. The core blocks are laid in place on the skin and fastened together into a single core-block with hand-heated pliers. Any internal members are usually added at this stage by cutting away the core to accommodate them, but sometimes small blocks are built around such members before being joined together. The core is trimmed slightly oversize with scissors, and the inner skin is laid on. The edge or closing members and joint straps are then added to the assembly and clamped in place. The whole assembly, on its fixture, is then placed in an oven and cured at a rigidly-controlled temperature for a specified time, under pressure applied by a vacuum blanket which forces the honeycomb close up against the sandwich skins and the outer skin against the flat face of the jig fixture. The size of component which can be produced is limited only by the size of the oven. The largest panel so far made is 11 m. by 1·2 m.

ELECTRONIC VACUUM BOND TESTER

After curing, the panel is inspected by an electronic flaw detector developed by the Avro company for checking that the bonding is secure. In this hand instrument, known as the vacuum bond tester, suction is applied over a small area of the skin and the deflection of the skin is detected by a feeler, the signal being amplified electronically to operate a red light if the bond is not secure. A green light shows that the bond is satisfactory. This instrument is also intended for use by maintenance staff at periodic inspections to ensure that the bond remains satisfactory.

This instrument clearly has interesting possibilities for the inspection of all types of metal-to-metal bonded structures, as for instance bonded stringer-to-skin combinations such as those used in the structure of Comet air-liners.

* * *

HYDRAULIC TESTING MACHINE FOR MOBILE LABORATORY

The illustration shows a small hydraulic testing machine which is now being produced by Welding Supervision, Limited, 73 South Audley-street, London, W.1. The machine, suitable for tensile and compression as well as bending tests on small specimens, weighs only 250 lb. but is capable of exerting a direct load of up to 15 tons. Yield, elongation and reduction of area can be obtained, and applied loads are indicated throughout the test.

The machine was first made to be carried in the mobile laboratories which the company operates to provide a comprehensive supervisory and inspecting service for contractors undertaking the welding of pipelines, storage vessels, etc. The laboratory is normally fitted with equipment for the radiographic inspection of welds, but apparatus for ultrasonic, magnetic and fluoroscopic testing can also be carried if required. This is in addition to facilities for the mechanical tests already indicated and a collapsible drawing board which can be used when sketches or other desk work is necessary.

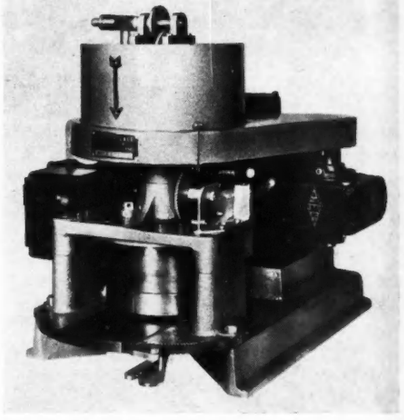
Hand-operated hydraulic testing machine suitable for mobile laboratories.

* * *

PULVERISING COAL

Machine for Grinding Samples

A machine of the " Hardgrove " type has been produced by H. W. Wallace and Company, Limited, 172 St. James's-road, Croydon, Surrey, for grinding coal samples to check their suitability for pulverising. The complete machine



Machine to test the suitability of coal for pulverising. It conforms with the A.S.T.M. standard.

is shown in the illustration above. It has been designed to conform with the American Society for Testing Materials tentative standard D409-37T but has been planned to allow for minor changes in the test which may be found desirable as a result of further research.

The grinding bowl or container is a unit complete with pestle and balls, which can be removed from the machine for filling and emptying. The base of it, which forms the grinding area, is detachable, being held in place by bolts, and can be changed if it is desired to use another shape or a different material. In use, the loaded bowl is pushed along the slide into its working position. Moving the lever at the bottom then raises the bowl, locating it in its station and clamping it against a rubber gasket which forms a dust seal. The drive to the pestle is then engaged by the lever at the top, the operation of which also applies the specified load of 64 lb. Then the motor is started by push buttons and rotates the pestle at 20 r.p.m. for exactly 60 revolutions, after which it stops automatically. The drive and clamp are disengaged and the bowl can be removed for inspection of the contents.

The drive shaft which engages with the pestle is mounted in Oilite bushes between which is packed felt saturated in oil. This arrangement is designed to give continued running without maintenance. Another felt washer at the lower end prevents dust from entering the bearings. The drive from the $\frac{1}{4}$-h.p. motor is geared down to 90 r.p.m., the final drive to the pestle spindle being by an 8-mm. roller chain with a speed reduction to 20 r.p.m. This chain is fully guarded. An electrically operated brake on the motor brings it to rest when the cycle is complete within one quarter of a revolution of the pestle, the prescribed tolerance for the operation.

INDUSTRIAL SPACE HEATERS

Automatically Controlled and Oil-Fired

A range of oil-fired fully automatic industrial space heaters, the Dravo Counterflo, is now being manufactured in England by the Coventry Radiator and Presswork Company, Limited, Coventry, under licence from the Dravo Corporation, Pittsburgh, U.S.A. The sole sales and servicing agents in the United Kingdom are Weatherfoil Heating Systems Limited, 185 Bath-road, Slough, Buckinghamshire.

With the Dravo Counterflo heater, a combustion efficiency of 80 per cent. is guaranteed. Designed for simple installation, reliability in operation, and easy and infrequent servicing, the unit is constructed in steel throughout, mounted on an angle-iron base, with an outer casing not less than 16 s.w.g. thick. Between the stainless-steel combustion chamber and the casing is a radiation shield. Access to the combustion chamber is facilitated by a removable panel on which the oil burner is supported. The latter has its own access door on the same support panel.

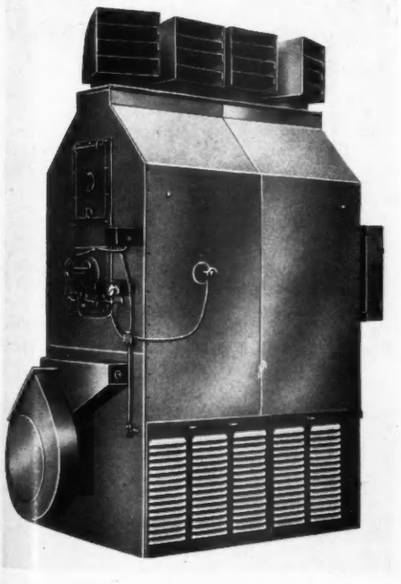
Air is drawn in through louvred grilles at the base of the heater by double-entry centrifugal fans, belt-driven by a 400/440 volt 50-cycle three-phase motor cooled by the incoming air, as are also the bearings of the fans themselves. Air at a pressure higher than that in the combustion chamber is blown up outside longitudinally-disposed economiser tubes located just below the combustion chamber. The air then passes uniformly over the entire surface of the combustion chamber at high velocity, converges in a short plenum at the top, and is discharged in the desired direction through adjustable nozzles, which can be rotated about a vertical axis and are provided with horizontally adjustable louvres.

The furnace is of the four-pass type. The burner flame travels towards the rear of the combustion chamber, then sweeps up and to the front of the combustion chamber, whence it is drawn downward behind a stainless steel baffle in each corner into the economiser tubes, through the first pass of the horizontal tubes from front to rear, then back to the front through the second pass of tubes. To increase the heat transfer, the economiser tubes incorporate removable flue-gas twisters. From the front end of the economiser the gases pass to a collection chamber whence they are discharged, through suitable ducting, into a vent stack by a small exhauster fan mounted outside the heater casing at the front on the same shaft as the blower fans.

The burner, specially designed for the heater and suitable for light fuel oils, is of the high-pressure atomising type supplied with oil by a motor-operated pump assembly located in the base of the unit. Air for combustion, taken from the main air-supply fans, is introduced into the burner tube tangentially to ensure good mixing with the fuel.

The burner is protected against flame, power or ignition failure by an electronic flame-protection relay. In starting up, the latter is energised automatically to permit burner operation after the combustion chamber has been purged for a predetermined time. A thermostat responding to room temperature controls the burner and the fans automatically: a combined fan and limit switch serves both to start the blower and exhauster fans when necessary to dissipate the heat of the combustion chamber following burner operation, and to stop the burner when necessary to prevent the discharge air temperature from rising too high. The burner is also stopped in the event of failure of the main blower-fan drive.

The Dravo heaters are available in a range of six sizes with outputs from 400,000 B.Th.U. per hour to 1,500,000 B.Th.U. per hour, and corresponding oil consumptions of 3 gallons to 11·15 gallons per hour, and air throughputs of 4,500 cub. ft. to 17,000 cub. ft. per minute at 70 deg. F. The larger sizes are particularly suitable for economically heating large areas such as aircraft hangars and assembly shops, large warehouses, etc.



The Dravo Counterflo industrial space heater operates on light fuel oil and has fully automatic control and protection against flame, power and ignition failure, excessive air temperature, motor overload, or air-flow failure. It is available in capacities from 400,000 B.Th.U. to 1,500,000 B.Th.U. per hour.

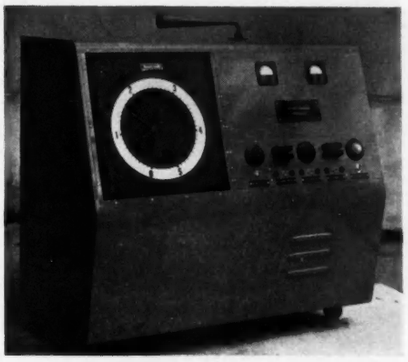
* * *

DETECTION OF TOXIC DUST CONCENTRATIONS

Instantaneous Monitoring of Factory Atmospheres

When certain elements such as beryllium and silicon are used for industrial processes there is a danger that dusts from these elements may reach a concentration in the atmosphere that is harmful. In the case of beryllium the tolerance figure is 2 micrograms per cubic metre; when this point is reached there must be some indication given, since continued inhalation of beryllium dust leads to a condition known as berylliosis. The essential of any method of testing the atmosphere is that the time between sampling and final analysis should be short. There are at present two main methods of analysing atmospheres: those involving chemical separation are lengthy even when the final assessment is by a spectrographic technique; filter methods of sampling, although accurate, are periodic, and cannot give immediate warning of high concentrations. The requirement for industries using beryllium is therefore an instrument giving a continuous indication of the amount of beryllium in the air at any moment.

A mobile direct-recording spectrographic monitor for beryllium in air has been designed by Dr. A. H. Gillieson of the Atomic Energy Research Establishment, Harwell, and is being developed and produced by Winston Electronics, Limited, 1 Park-road, Hampton Hill, Middlesex. The air to be sampled is drawn through the gap between two copper electrodes between which a spark discharge is passing, in a chamber constructed so that the spark is observed along the axis of the flow of the entering air, but in the reverse direction. In this way window obscuration by the copper-oxide particles thrown off by the discharge is prevented. The light from the spark is focused on the slit of a small specially-designed Littrow-type monochromator which has a multiplier photocell behind its exit slit; the photomultiplier signal operates a circular chart recorder through a direct-current amplifier. The indication is only semi-quantitative since the response is affected by particle size, but in the calibration comparisons which have been run with filter samples and under actual factory conditions, the monitor figures have been within a factor of 2 at the very low levels of the tolerance figure (2 micrograms per cubic metre). At higher levels the accuracy increases rapidly.



The spectrographic monitor gives an instantaneous reading of the amount of certain toxic dusts in the atmosphere.

The instrument has been proved to respond to beryllium in the form of the oxide (as furnace fume and as dust), of the fluoride and ammonium double fluoride, and as beryl ore. It has been used to determine the hazard in filling mobile containers with powdered ore, in operating a briquetting press for furnace charges, in the operation of an ammonium-beryllium fluoride drier, and in the firing of beryllia ware in a gas-fired furnace. In the last case, it was possible to examine the efficiency of the exhaust system of the furnace and to indicate the adverse effect of "air screen" introduced to prevent fumes escaping into the laboratory. The contamination of factory floors and workpeople's clothing has been checked.

The instrument has only been tested on one other element providing a toxic hazard, namely, silicon, but it could be applied to a number of such elements including lead, chromium, antimony and manganese.

EXPANSION INTO NEW FACTORY

The spectrographic monitor was one of a number of items of electronic equipment shown recently by Winston Electronics, Limited. They are shortly moving from their premises at 1 Park-road, Hampton Hill, to a new factory at Shepperton. On December 20, 1954, a stone was laid at the new factory by Mr. John D. Profumo, M.P., Parliamentary Secretary to the Ministry of Transport and Civil Aviation. Mr. Profumo spoke of the increasing use of electronic equipment in industry generally and in aviation in particular; he also mentioned the opportunities for firms such as Winston Electronics to make specialised electronic equipment which could not be produced so economically by larger firms.

* * *

INDEX TO "ENGINEERING"

Volume 177 now ready

The Index to Volume 177 of ENGINEERING (January-June, 1954) is now ready and will be sent to any reader, without charge and postage paid, on application being made to the Publisher, 35 and 36, Bedford-street, London, W.C.2. Any reader wishing to receive regular copies of the Index as they are published can apply to be put on the mailing list. Those already on the mailing list need not re-apply.

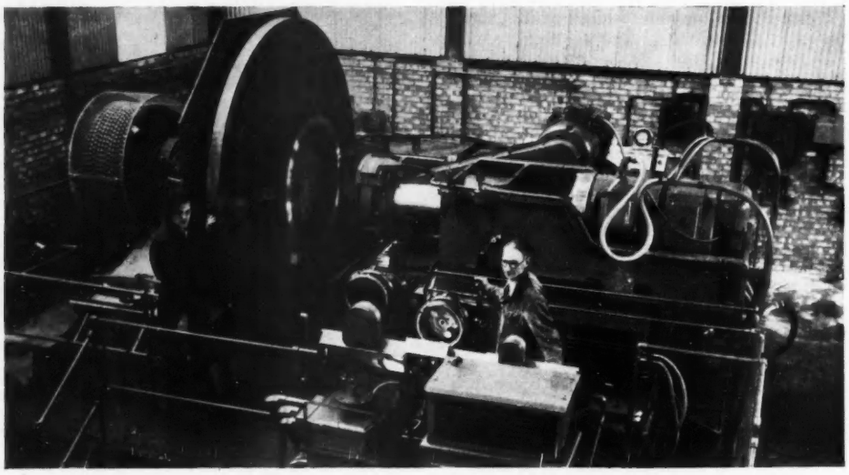


Fig. 1 The 108-in. universal grinding machine designed by the Cooper Roller Bearings Company, Limited, will carry out parallel internal and external grinding, face grinding, as well as the grinding of tapers and spherical forms.

GRINDING LARGE BEARING RACES

UNIVERSAL MACHINE FOR DIAMETERS UP TO 108 IN.

The Cooper Roller Bearings Company, Limited, King's Lynn, Norfolk, commenced the manufacture of their well-known split roller bearing in 1907. Since that date the range has been extended, and roller bearings, both split and solid, have been produced regularly up to 55·5 in. bore. In recent years a demand has developed for still larger sizes, and in 1950 the Company decided to acquire a machine which would be capable of grinding races of over 100 in. in diameter. No suitable machine was available commercially, and it was therefore decided to design one to meet the required specification, manufacturing such parts as were within the Company's capacity and obtaining the remainder from outside sources. Accordingly, a design was prepared by the Company's technical staff, under the leadership of Mr. S. Kay, M.B.E., A.M.I.Mech.E., director and chief engineer, and the machine has now been erected at King's Lynn and subjected to extensive tests. Fig. 1, above, shows the machine as installed and Fig. 4 is an arrangement drawing of it.

The machine, which is claimed to be the largest of its kind on this side of the Atlantic, is capable of internal, external and face grinding, and will swing work up to 10 ft. 6 in. in diameter and 2 ft. 7 in. long. Face grinding is possible up to 9 ft. diameter and external grinding up to 10 ft. diameter. Internal grinding can be carried out up to a diameter of 10 ft. less twice the wall thickness of the article being ground. The maximum length for both internal and external grinding is 2 ft. Faces can be ground up to 9 ft. diameter on work not exceeding 10 ft. 6 in. in diameter, and the radial width of face grinding can be up to 24 in. or more in many cases. The machine will also grind tapers up to a maximum angle of 8 deg. (that is, cone apex angle 16 deg.), and special forms such as spherical shapes for ball races.

Most of the component parts of the machine were too large to be made at the Company's works, and their manufacture was therefore entrusted to other concerns. The principal contractors were Buckley and Taylor, Limited, Oldham, who were responsible for the castings, and the machining and fitting of all the heavy components. The Newall Engineering Company, Limited, Peterborough, made the hydraulic gear and also the mechanical lubrication equipment. Various finished parts, including the face-plate, work-head top slide, facing-spindle top slide, and work-head swivel slide were made by Baker, Perkins Limited, Peterborough and the grinding of the work-head spindle was undertaken by Peter Brotherhood Limited, Peterborough. Erection of the machine at King's Lynn was carried out under the supervision of the Company's chief engineer.

The machine has a total weight of 65 tons, and is mounted on a bed 18 ft. by 18 ft. The overall height is 11 ft. 6 in. Cooper split roller bearings have been used in the construction of the machine, which has radial, ball thrust and parallel roller thrust bearings. The total electric motor horse power is 130.

Tests have shown that the accuracy and sensitivity of the machine are exceptional, and the rate of stock removal, 40 lb. of metal per hour, is more than four times greater than can be achieved on the Company's previous largest machine. On normal production work an accuracy of 0·0001 in. in diameter, roundness and parallelism is regularly obtained, and diameters can be repeated from piece to piece to within 0·0001 in. of the required dimension over the full range of the machine. One of the control panels is shown in Fig. 2, and an example of face-grinding in Fig. 3.

FACE-PLATE WORK-HEAD

The work to be ground is mounted in a jig on a 9-ft. diameter face-plate, grinding being carried out in two stages, roughing and finishing. During rough grinding the work is firmly clamped to the jig, but is released at intervals to relieve any stresses in the ground part. When finish grinding, the work is clamped lightly, and light cuts are made, with coolant flowing at a rate greatly in excess of that necessary for the required surface finish, in order to obtain the maximum possible cooling effect. When races require grinding on the side faces, the jig is re-ground for each component.

Gauges for work measurement are of the Company's own design and manufacture, and are made in multiples of 1 in., the fractions being measured by a micrometer thimble. They are kept in the coolant storage tank when not in use, in order to ensure that they are at the same temperature as the work. Bores are measured in the vertical position by a point-gauge, and outside diameters by a micrometer in the horizontal position. The micrometer is then supported at the same points and in the same plane as when it is checked with the master gauge. Prussian blue or a similar marking agent is used to detect the first touch of the micrometer spindle, and thus eliminate possible errors due to individual " feel."

The face-plate, which is slotted for accommodating clamping bolts, is carried on a 14-in. diameter grease-lubricated spindle which has a V-belt pulley at its outer end. The drive is from an electric motor through V-belts to a P.I.V. gearbox, thence by a coupling to a worm gearbox, and finally by a further coupling to a V-belt pulley, from which belts are taken to the pulley on the face-plate spindle. Induction regulation of the alternating-current motor enables the face-plate to be rotated at speeds varying from 1·475 to 19·5 r.p.m.

The complete work-head is slide-mounted, and is capable of traversing 5 ft. 3 in. along its bedplate to allow for different diameters of work. Traverse is by means of a lead screw, driven by an electric motor through a worm gearbox. A scale calibrated in work and wheel diameters for both internal and external grinding enables the work-head to be positioned accurately, ready for grinding. In addition to being slide-mounted, the work-head is also pivoted, and can be swivelled through an angle of 8 deg. for taper grinding, the approximate setting being by electric motor and the final setting by hand-wheel, with micrometer adjustment. Control of the work-head drive is by push-button, and

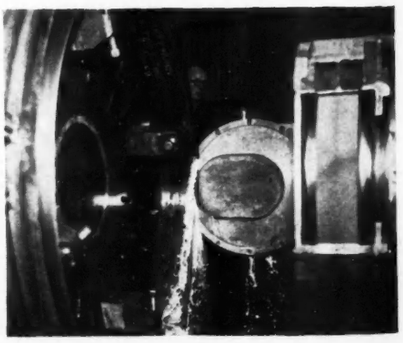


Fig. 3 Face-grinding a large bearing race. Coolant is supplied through the spindle and grinding wheel.

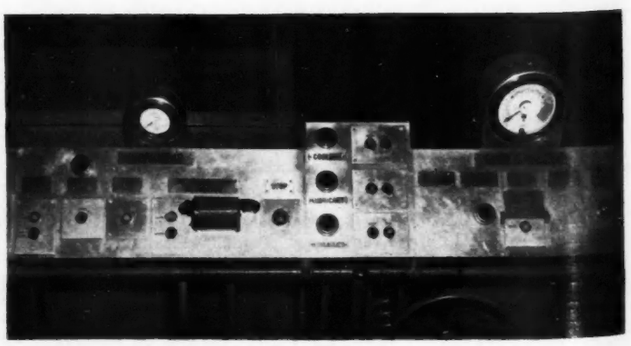


Fig. 2 Controls are grouped on duplicate panels, one on each side of the machine.

an electro-magnetic brake operates automatically when the stop-button is pressed.

TWO INDEPENDENT GRINDING HEADS

The machine is provided with two independent grinding heads, one for all facing operations and the other for all internal and external grinding. The maximum grinding wheel sizes are: internal and external grinding, 24 in. in diameter by 6 in. face width; face grinding, 18 in. in diameter by 3 in. face. Both wheel guards are fitted with a pre-set safety device which prevents the maximum safe speed for any given diameter of wheel from being exceeded. Provision is also made for diamond dressing of the wheels. Both wheels are independently motor-driven, and their speeds can be controlled from 3,500 to 6,500 ft. per minute by induction regulation of the alternating-current driving motors.

Hydraulic rams are provided for movement of the grinding-wheel heads, the face-grinding head having a traverse of 2 ft. 10 in., while the cylindrical-grinding head can travel through a distance of 2 ft. 7 in. Hydraulic control valves enable the traverse rate to be varied from 1 to 48 in. per minute; reciprocating motions are also available for cylindrical and face grinding operations. Initial movement of the grinding heads is carried out with the hydraulic feeds motions; fine setting can be carried out on each motion by hand-wheels and screws with gripper-nuts and fine-feed gearboxes, which enable the heads to be moved manually against the hydraulic pressure and give wheel advancements of 0·0001 in. Adjustable mirrors are fitted to enable the machine operator to see the actual grinding contact.

The grinding wheels are provided with coolant by two motor-driven pumps, each supplying 24 gallons per minute. Coolant is circulated through the spindle and grinding wheel, and returned by drip-trays to a storage tank, where it is filtered before being re-pumped to the grinding heads.

All slideways are provided by pump with lubricating oil at 150 lb. per sq. in. pressure, and hand pumps are also fitted to introduce a graphite solution at intervals. The lead screws are also automatically lubricated, and oil is pumped to the work-head, where it lubricates the swivel and traverse bearings.

DUPLICATED CONTROLS

All the electrical controls are grouped on duplicate panels, one on each side of the machine. In addition to the control push-buttons the panels are equipped with tachometers indicating work speed and wheel speed. The tachometer dials are calibrated to read in revolutions per minute of the spindle, peripheral speed of the grinding wheel in feet per minute, and horse-power of the motor, corresponding with the speed and power input to the motor driving the spindle in use. A power input meter is also mounted at the centre of the machine, and arranged to swivel so that it can be seen from either control position. By comparing this instrument with the reading of the power available on the appropriate tachometer dial, the operator can determine how much of the available motor power is being used, and thus keep the machine working to its maximum capacity.

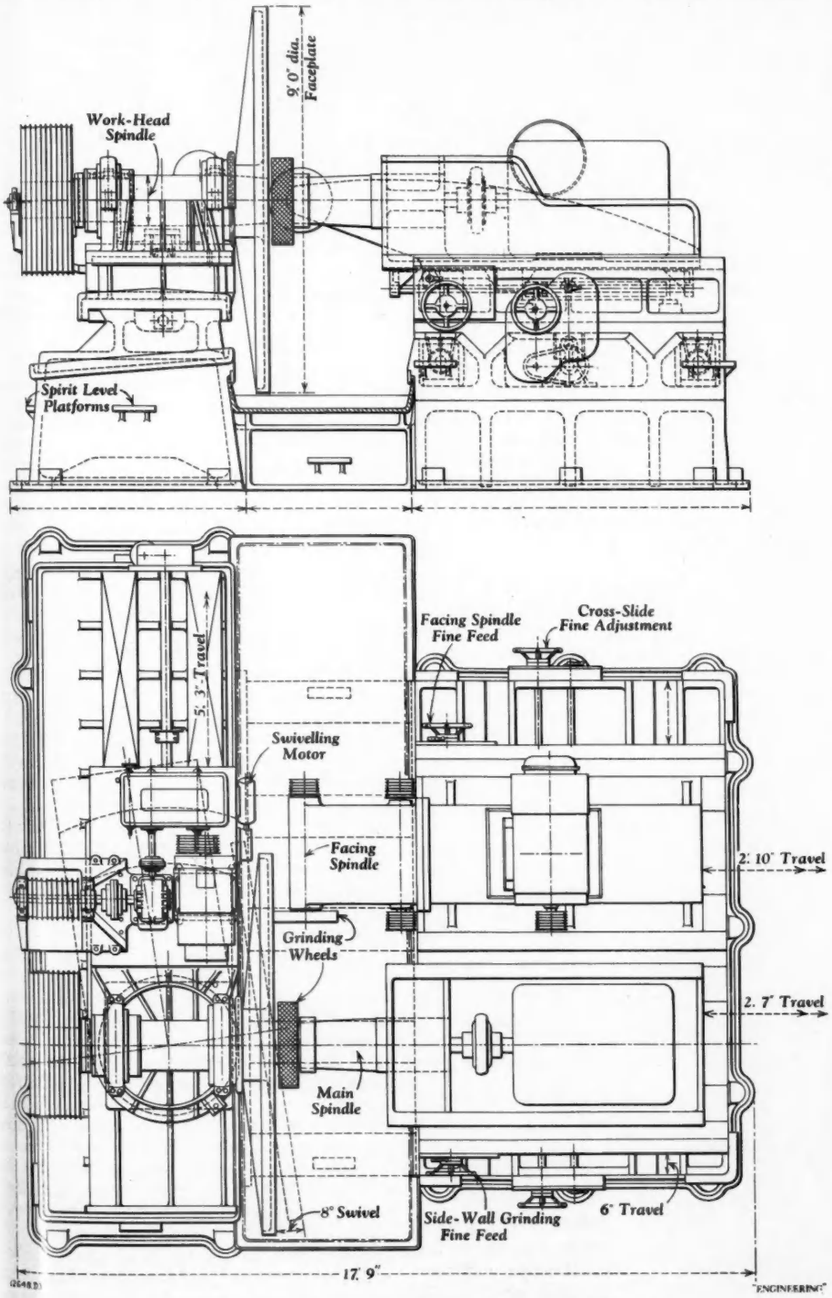


Fig. 4 General arrangement of 108-in. universal grinding machine.

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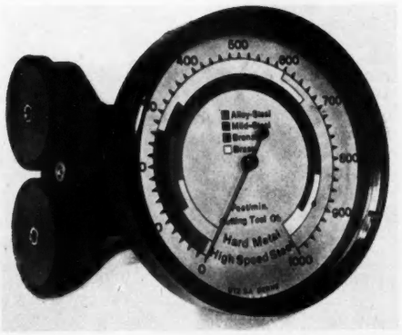
CUTTING SPEED INDICATOR

Dial Shows Safe Limits

An instrument which shows at a glance the cutting speed of a machine tool, and whether or not that speed is appropriate to the material it is cutting, has been made by UTZ, Limited, Berne, Switzerland; their agents in England are Fred Ferraris, Limited, 14 Northampton-square, London, E.C.1. The accompanying illustration shows how simply the instrument is operated; the two rollers are placed on the surface being cut, and the cutting speed is read off on the indicator. The dial of the indicator is marked as shown in the illustration; the outer scale shows cutting speed in feet per minute; the two inner rings refer to two materials of which a cutting tool may be made, high-speed steel or cemented carbide. Each ring is marked off in arcs corresponding to the optimum cutting speeds for alloy steel, soft steel, bronze, and brass respectively. With the help of this cutting speed indicator and without preliminary calculation the operator can run his machine at the highest speed the cutting tool can withstand.



This indicator shows the cutting speed of a machine tool in feet per minute, and indicates speed limits for cutting various materials with two types of tool. Contact by the two wheels ensures accurate measurement.

STANDARD HYDRAULIC RAMS FOR GENERAL PURPOSES

FOUR RANGES BASED ON SEVEN CYLINDER BORES

Four series of standard hydraulic rams have recently been introduced by Chamberlain Industries, Limited, of Staffa Works, Leyton, London, E.10, with the object of simplifying production and providing versatile and economic units for a wide range of general applications. Rams are normally made in conjunction with particular items of equipment or in small numbers to a given specification, but in accordance with their experience of requirements over a long period, Chamberlain Industries are making a standard range, based on seven fixed cylinder bores. The four different designs embraced by the range are: low-pressure and high-pressure solid rams, hollow rams, and high-pressure short-stroke rams. Loads from 1 ton to 100 tons can be accommodated. Fig. 1 shows a high-pressure ram of 10 tons nominal capacity, as fitted to a Staffa 2-ton hydraulic shop crane. The hollow rams are believed by the makers to be the first of their kind built in this country as a standard range, and have uses which include the forcing home of cylinder liners and the prestressing of concrete.

Fig. 1 High-pressure ram of 10-tons nominal capacity. It is one of a range based on seven standard cylinder bores which also form the bases of three other ranges.

The four types of ram have been designed on a basis of the seven standard cylinder bores which appear in the list of dimensions given in the table; although the cylinders have different outside diameters in accordance with high-pressure or low-pressure requirements, the seven internal diameters remain unaltered, irrespective of operating pressures or application. The ranges of solid rams and short-stroke or "tubby" rams make use of all seven bore sizes, but for practical reasons the smallest cylinder is not employed in the range of hollow rams. The adoption of this principle enables economies in equipment and materials to be achieved.

LOW-PRESSURE RAMS

The seven Staffa low-pressure rams, one of which is shown in section in Fig. 2, give nominal thrusts at 2,000 lb. per square inch ranging from 1 to 40 tons. The rams can be single or double acting, and are made for use with a number of different fittings for the piston end, and for the upper and lower ends of the cylinder; the interchangeable piston-end fittings are: plain, plain with crosshole, nose, nose with crosshole, and eye; for the cylinder, plain or flanged fittings can be attached at the piston-rod end, and plain, eye, or base fittings at the bottom.

The ram consists basically of a cylinder of cold-drawn seamless tubing, bright as drawn and honed. The bottom end fitting is welded to the cylinder, which is located on a machined spigot. The top end fitting is machined from a high-grade iron casting, and is held on the cylinder by a steel ring nut or by a flange fitting. A counter bore in the flange fitting is located on a split ring, which fits into a square groove turned on the outside of the cylinder. This method of construction reduces the machining on the cylinder to a minimum and ensures that parts of the cylinder subjected to full hydraulic pressure are of maximum cross-section.

The piston rod and piston are welded together and machined as a single item on a Drummond-Asquith "Maxicut" electronic copying lathe; the unit is then ground and chromium plated. In certain applications, however, in which bending for example is involved, the piston rod might be of bronze or cast iron, and in that case only the piston would be machined in the manner described. Tubular piston rods are employed on the larger versions. Rust prevention by plating is an important consideration since small areas of rust can cause serious damage to hydraulic seals; chromium plating therefore not only extends the life of a ram but also simplifies maintenance.

It should be emphasised that welding is only employed in the low-pressure rams. Chamberlain Industries are already experienced in the production of welded components for hydraulic units, and to ensure that welds are homogeneous, the use of automatic welding plant is proposed.

Chevron packings form the joint between the top end fitting and the piston rod, and can be adjusted by means of gland nuts. Synthetic-rubber U-seals are fitted to the piston. Single-acting rams are similar to double-acting models except for the top fitting, from which the oil-feed connection is omitted; the chevron packing is then replaced by a larger bronze bush. Standard rams have strokes up to 36 in. but versions with longer strokes can be made.

Bore Size and Dimensions of Standard Ram Cylinders

Bore Size	High Pressure			Low Pressure		
	Outside Diameter, in.	Inside Diameter, in.	Thickness, in.	Outside Diameter, in.	Inside Diameter, in.	Thickness, in.
1	2⅛	1½	⅜	2	1½	¼
2	3⅛	2½	⅜	2⅝	2½	⅛
3	4⅛	3½	⅜	3⅛	3½	⅛
4	5½	4½	½	4⅛	4½	⅛
5	7	5⅝	⅝	5⅛	5⅝	⅛
6	8½	6½	1	7⅛	6½	⅜
7	9½	7½	1	8½	7½	⅜

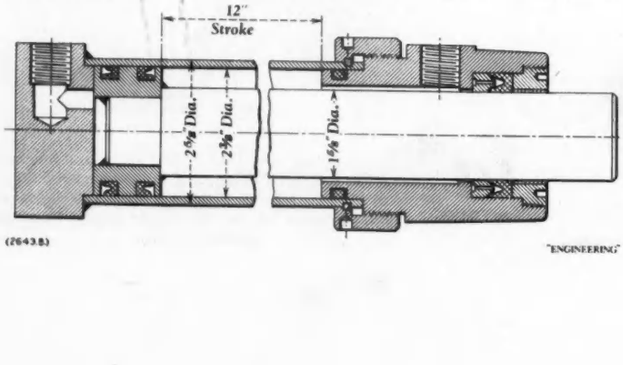


Fig. 2 Sectional view of Staffa low-pressure ram. Rams in this range are of welded construction and may be used with various standard end fittings.

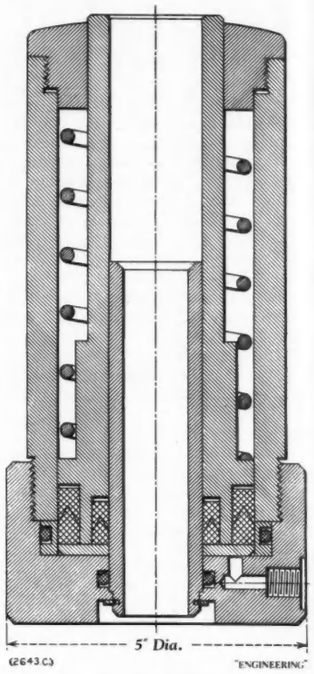


Fig. 3 High-pressure hollow ram suitable for applications involving pulling, such as the prestressing of concrete reinforcement and removing pins from crawler tracks.

Fig. 2 shows in section a 4-ton double-acting ram of 12-in. stroke. As is evident from the drawing there are no screw threads on the cylinder to serve as sources of weakness or cracks, and the O-ring at the upper end of the ram prevents fluid under pressure making contact with the weaker cylinder section at the circlip.

HOLLOW RAMS AS EXTRACTORS

Fig. 3 is a sectioned view of a Staffa high-pressure spring-return hollow ram and indicates the method of construction adopted. This series includes rams of six sizes with load-carrying capacities from 7 to 85 tons; the one illustrated has a maximum outside diameter of 5 in. and can support a load of 15 tons. Six only are made since the smallest standard cylinder bore would not be large enough to accommodate internal components of sufficient size to provide a practicable unit.

In this series, a hole drilled coaxially in the piston rod enables the ram to be used for pulling, and thus for numerous applications as an extractor. Rams of this kind have served widely abroad for removing track pins and sprocket wheels from crawler tractors. Staffa hollow rams are suitable for this purpose and the makers believe that the practice, which has been little tried in Britain, might profitably be extended to this country. Other uses for hollow rams include the prestressing of reinforcing members in concrete, the removal of retaining wedges in the launching of ships, and the insertion of cylinder liners and other components requiring a force fit.

The strokes of the hollow rams are approximately equal to the bores of the cylinders, which have been designed to withstand a pressure of 5,000 lb. per square inch. In certain circumstances, however, pressures up to 6,000 lb. per

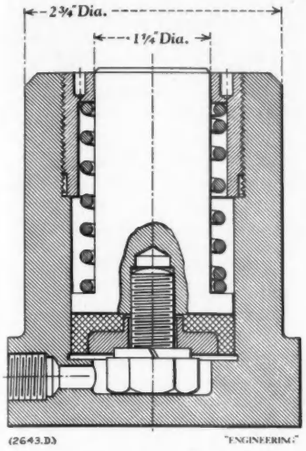


Fig. 4 The series of seven single-acting spring-return tubby or short-stroke rams can support loads ranging from 5 to 100 tons.

square inch can be employed, and in a few cases, depending on the length of stroke, still higher pressures are possible. These values can of course be further improved by the use of special steels of higher tensile strength than the EN.8 steel used as standard in the construction of the units; the higher the tensile strength of the cylinders, the higher the permissible pressures. All the principal parts are either cast or machined from solid bar so that the risk of fracture or hydraulic leak is minimised.

HIGH-PRESSURE SOLID AND SHORT-STROKE RAMS

The standard series of high-pressure solid rams comprises seven sizes, capable of nominal thrusts ranging from 5 to 100 tons at 5,000 lb. per square inch and are either double or single acting. The cylinders are made from cold-drawn seamless steel tube or from bored billets; the method employed is determined by the diameter.

Unlike the low-pressure units, in which welding can be permitted, all three types of high-pressure ram incorporate screwed joints; the end fittings of the solid rams screw over the outside of the cylinders thereby giving additional strength at the threads. Standard models with strokes up to 12 in. are made, but certain sizes can be built to have longer strokes for particular applications. The seal packings used for moving joints are of chevron pattern.

The short-stroke or tubby ram shown in section in Fig. 4 is one of a series of seven with nominal thrusts ranging from 5 to 100 tons at a pressure of 5,000 lb. per square inch. These rams are single acting with spring return, and a standard stroke of 1 in. is common to all sizes. They are useful for providing heavy thrusts in very confined spaces, and can be employed as extractors or for such applications as the moving of machinery.

Units incorporating standard and special rams designed for particular purposes are also made by Chamberlain Industries, as well as pumps and other equipment operating at pressures up to 10,000 lb. per square inch.

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In an article entitled "Practical Smoke Abatement; Use of smoke eliminator fire door," published in ENGINEERING for December 17, 1954, there was an error in the caption to Fig. 2. The (a) and (b) of Fig. 2 (a) and 2 (b) should be transposed, so showing that the amount of smoke produced when using the smoke eliminator fire-door is very small compared with that produced when using a normal fire-door fitted with a proprietary device.

AUTOMATIC CONTINUOUS CENTRIFUGE

SEPARATING, WASHING AND DE-HYDRATING CRYSTAL SLURRIES

An automatic continuous centrifuge of the perforated basket type designed for separating, washing and dehydrating all grades of slurries of crystals, is now being manufactured in Great Britain by Sharples Centrifuges Limited, Tower House, Woodchester, Stroud, Gloucestershire. Known as the Super-D-Hydrator, it was previously available only from the company's Philadelphia (U.S.A.) factory.

The Super-D-Hydrator is shown in the accompanying illustration. The basket is arranged to rotate at constant speed about a horizontal axis. The admission of crystal slurry to the rotating basket is regulated automatically until a crystal layer 2 in. to 3 in. deep has built up. A leveller-arm actuated by a hydraulic snubber mechanism ensures that an even layer of crystals is formed.

Crystal washing is effected by one or more automatically-controlled rinses. After a final period of spin to remove liquor from the crystal bed, the basket load is discharged by a hydraulically-operated rising knife that cuts into the layer of crystals and delivers them through a discharge chute. A thin layer of crystals is retained on the screen to provide a filter medium for the next load, thus permitting the use of a larger mesh than would otherwise be possible, and giving higher liquor-drainage rates. This crystal layer is generally kept about $\frac{1}{16}$ in. thick.

Where there is a tendency for the crystals to glaze, it is necessary to perforate the layer with a mild solvent wash, the "screen rinse," using a suitable liquid, generally water or steam. This rinse is introduced automatically at the beginning of each cycle.

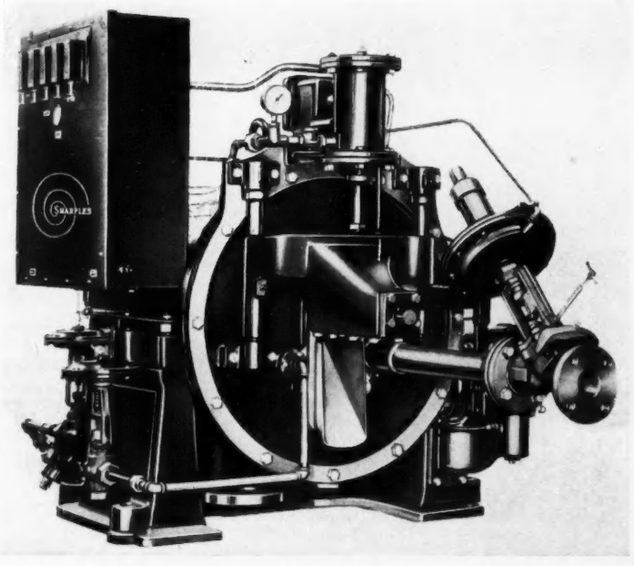
A typical operating cycle, which may occupy from 20 seconds to 20 minutes, depending on the nature of the crystals being handled and the complexity of the cycle, comprises the following automatically controlled steps:—screen rinse, load, spin idle, cake rinse, spin de-hydrate, discharge. Where necessary, a number of different liquors may be used for cake-rinsing—e.g., a neutralising liquor may be used for the primary wash, followed by water. The molten liquor and rinse liquors can be kept separate by an automatically-controlled diversion valve on the frame drain outlet.

The time intervals of each step in the cycle can be varied independently, while the machine is running, to suit variations in the condition of the feed slurry or to alter the purity or dryness of the products. All the intervals are controlled by electric timers of the cycle-stop type, graduated in seconds; thus each timer operates through its cycle after being set in action by a starting impulse, energises the next timer in the cycle and then resets after the unit is de-energised, to start again at the appropriate moment in the next cycle.

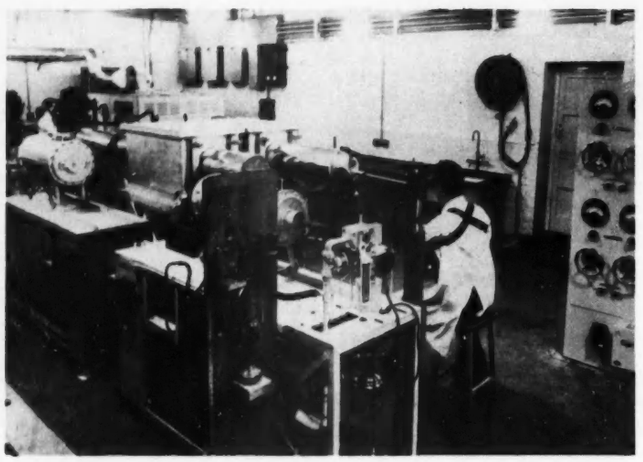
The various circuits energised by the electric control timers operate electro-pneumatic relay valves in the control relay section. Air passed by these valves actuates diaphragm valves in correct sequence on the slurry, wash-liquor, and hydraulic-actuating circuits. The control relay is mounted on the frame or adjacent to the machine, the control-timer being located on a convenient wall or in a control room. Each step in the cycle can be controlled manually by switches until the optimum time intervals for each step have been determined. The switches are then put to the automatic position, and the determined time intervals set on the time-cycle controllers.

The version of the Super-D-Hydrator illustrated is of the "open" type, suitable for handling non-toxic non-volatile materials. For toxic or hazardous materials, a Vaportite version is available with the discharge chute enclosed in a hood. Flameproof wiring and electrical controls are fitted where necessary. The frame and hood of the Vaportite centrifuge can, if required, be filled with inert gas, or can be supplied with provision for steam-sterilising the contact parts of the machine when such precautions are required.

The manufacturers claim that, owing to the thin cake used and its even form, excellent washing can be obtained leading to a product of higher purity than is possible with a batch machine; and since it operates continuously, the power consumption of the Super-D-Hydrator is considerably less. By using centrifugal forces of 1,200*g* or more, a relatively small basket load can be handled very rapidly in each cycle, and with the thin crystal layer, a high mean drainage rate and low final moisture contents are achieved.



The admission of crystal slurry to the centrifuge is automatically controlled by a hydraulic mechanism, and the sequence and timing of the entire cycle of operations, including the final discharge, is automatically controlled by electric timers through pneumatic or hydraulic actuators.



Vacuum and controlled atmosphere sintering furnaces in the Heat Treatment Laboratory.

TOOL-MAKING RESEARCH

New Laboratory for Firth Brown Tools Limited

The demand for machine tools increases as production from the engineering industries rises, and machine tool makers must always be seeking new materials and methods to speed machining processes in industry. For the greatest efficiency a machine tool research department must be designed specifically to examine new materials and methods of manufacture, and to check that production standards are maintained. Firth Brown Tools, Limited, Carlisle-street East, Sheffield, found their existing research department inadequate, and on January 13, 1955, the Master Cutler, Mr. W. G. Ibberson, opened their new research laboratories in Windsor-street, Sheffield.

The building chosen for the new laboratories had previously been used for other purposes, but had the advantage of being relatively vibration free. This was essential for the department, and was difficult to find in an area so largely devoted to heavy industry. The building was redesigned internally and air-conditioning plant was installed; the result is a research department free from dust and vibration, divided into eight laboratories.

The metallographical laboratory is equipped for the examination of the microstructures of tool steels, hard metals and hard abrasive compounds. The main equipment is a Vickers projection microscope for the visual examination and preparation of photomicrographs; medium power binocular microscopes are provided for the micro-examination of cutting tool specimens. There is the usual apparatus for the preparation of specimens for micro-examination, including grinding, lapping and polishing with graded diamond dust. This is a necessary provision since most of the specimens examined are extremely hard.

Before examination, specimens can be either etched or "heat tinted"; heat tinting is a process for the micro-examination of hard metals of the multi-carbide type; it has the advantage that with careful control the various carbides are coloured in different ways and can be readily identified on examination.

In the analytical laboratory raw materials are analysed to ensure that they are within the specifications laid down, and the intermediate and final products, are analysed as a check on production processes. As an illustration of this, the analytical work connected with "Mitia" hard metal manufacture involves analyses on wolfram-ore, intermediate products such as ammonium paratungstate and tungsten metal, alloy powders containing tungsten carbide, titanium carbide, tantalum carbide and cobalt, as well as the final hard metal. Analyses ensure not only the control of harmful impurities, but also the correct proportions of the constituents.

It is important to detect trace elements in modern tool materials because they can have a marked effect on cutting tool performance. A flame photometer has been installed and is used for the rapid determination of sodium and calcium present in small amounts in the tungsten compounds used. Spectrographic analysis is a quick and convenient method of detecting trace elements, and the spectrographical laboratory is equipped with a Hilger automatic large quartz spectrograph. All the necessary ancillary equipment for the use of the spectrograph has also been installed.

The heat treatment laboratory, shown in the accompanying illustration, can carry out any heat treatment work involved in tool manufacture under carefully controlled conditions. There are high-temperature conditioned-atmosphere furnaces which will operate at temperatures as high as 1,650 deg. C., and vacuum furnaces which will operate up to 1,400 deg. C. with a vacuum of 0·001 mm. mercury absolute pressure. Small salt-bath furnaces are installed for the heat treatment of carbon, low-alloy and high-speed steels together with small tempering furnaces for development work on "speedicut" tools made from these materials. A 30-kW high-frequency furnace is also provided, working on frequencies of 175 to 300 kilocycles per second. The furnace is to be used for experiments on heat treatment of tool steels, brazing of tool assemblies and on the preparation of tool materials by a modification of the powder metallurgy process which is known as hot pressing.

The work of the physical laboratory is largely concerned with the determination of the grain size of the considerable number of powders handled by the hard metal division of the company. This work is complicated by the fact that the particle sizes cover a wide range. Some powders have to be accurately sized in the range of 8 to 20 mesh while the finest powders are controlled to a grain size of less than 0·001 mm. To cover this range, apparatus is installed to enable a number of different methods of grain size measurement to be employed which include: sieving; microscopic measurement and counting; turbimeter and spekker light extinction methods; air permeability; water elutriation. Apparatus is also installed in this laboratory for the examination of magnetic and electrical properties.

Control of temperature is an important factor in the manufacture of small tools, because all heat treatment operations depend upon it. The pyrometrical laboratory is therefore equipped for the standardisation of all types of temperature measuring apparatus, including optical pyrometers. Thermocouples can be made as required and instruments can be repaired.

The experimental machine shop is provided in the first place to enable test specimens to be prepared. Due to the hard character of many of the materials handled, unusual methods of machining test specimens are necessary. These include machining by the "quenched arc" or "spark discharge" process. An "Erodomatic" machine is installed which is capable of cutting or drilling holes of any form in the hardest tool materials.

A laboratory is equipped for the mechanical testing of tool materials; there is a tensile testing machine, a variable load hardometer, and a Vickers hardness testing machine. More important than the material testing is the testing of cutting action of the finished tools. In the high-speed test lathe laboratory tools are tested, and the wear occurring during test is measured. In the test machine shop there are drilling, tapping, milling and other machines fitted with instruments to measure the power consumption and forces on the cutting tools.

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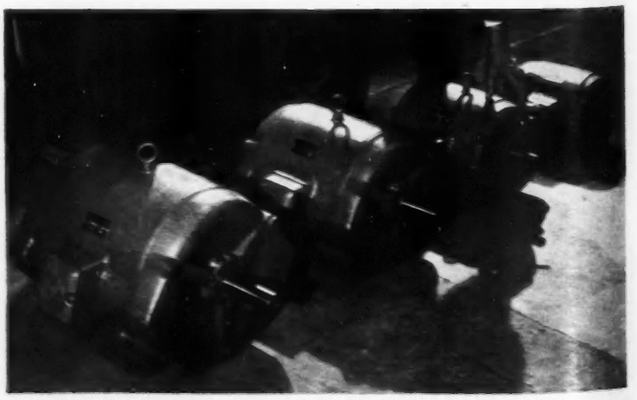
ELECTRIC MOTORS TO AMERICAN STANDARDS

The English Electric Company Limited, Kingsway, London, W.C.2, is now manufacturing a range of ventilated squirrel-cage induction motors with outputs ranging from ½ to 25 h.p. at any standard frequency and voltage. These motors comply with the revised standard of the United States National Electrical Manufacturers' Association (N.E.M.A.), which specifies dimensions smaller than the British standard and calls for four frame diameters. They are therefore suitable for manufacturers exporting machine tools to dollar areas as well as for users of American patterns.

The end shields of the new motors have wide flares to allow maximum air flow and the vents are fully protected. The axial fan rotates in a "trap" type cavity, so that there is an ample air stream, this ensuring cool running. The bearings are of metric size.

The motors comply with British standard specification No. 168 of 1936 and have been approved by the Canadian Standards Association. As an example of the reduced size, the height of the shaft centre of a 2-h.p. four-pole motor in the new range is 4½ in., compared with 5 in. for a British standard totally-enclosed motor and an original N.E.M.A. motor of the same output.



English Electric ventilated squirrel-cage induction motors showing the four N.E.M.A. standard frame sizes.

Labour Notes

SHOP STEWARD DISPUTE

Disagreement between employees of Wright and Platt, Limited, Birmingham, and the firm's management, regarding the appointment of a shop steward, led to strike action being taken on January 10 by some 50 patternmakers on the company's staff.

The trouble appears to have arisen when the management declined to recognise as a shop steward a man elected to that position by other employees in his department. As a protest, the men concerned went on strike and were dismissed on the following day.

Negotiations between the firm and the United Patternmakers Association, to which the men belong, continued throughout the remainder of last week. There were strong hopes at one time that the difficulty would be settled quickly, but these expectations were not realised.

Last Friday, the company agreed to reinstate all the men, including the man nominated as shop steward, but refused to change its decision regarding his recognition in that position. At a meeting on Saturday, the men decided that, as the recognition of their nominee was the issue on which they took strike action, they would continue the stoppage.

Commenting on the origin of the dispute, an official of the company stated that an ultimatum was given to the management on January 10 that, if the employee nominated as shop steward was not accepted by a specified time, the men in his department would cease work. The firm's reply was that, in that case, those concerned would be dismissed.

NEED FOR RAILWAY MODERNISATION

References to the general need for the modernisation of the railways were made by Mr. J. Campbell, the general secretary of the National Union of Railwaymen, at a meeting of the union in Bristol on Sunday.

As far as the engineering side was concerned, Mr. Campbell said, it was not sufficiently realised that railway employees had to manhandle heavy merchandise. There were, moreover, many engines in use which should have been put on the scrapheap years ago. These should be replaced as soon as possible.

Mr. Campbell also strongly condemned the appointment to railway boards of management of men from outside the industry. He considered that some of the persons appointed " to run the railways " had little direct knowledge of the industry, and suggested that few things would have been easier than to have found suitable persons for appointment from among the 560,000 railwaymen employed by British Railways.

It would, he felt, have done a great deal of good to have given such responsibility to some of these men and they would have discharged the duties with much efficiency.

CRITICISM OF UNOFFICIAL STRIKE LEADERS

Some outspoken comments on the ways of leaders of unofficial strikes are contained in the January issue of *Man and Metal*, the official journal of the Iron and Steel Trades Confederation, which was published on Saturday.

Mr. Harry Douglass, the Confederation's general secretary, states in his editorial: " How unofficial strike leaders love to attach the title of militancy to their activities! They claim to be the people who carry the banner of freedom, the people who have the ' guts ' to fight the employers, the people with the courage to organise strikes, and the people who push up wages.

" All this is, of course, sheer humbug, as the number of times unofficial leaders tell their dupes to return to work ' because the management has agreed to examine their claim ' reveals." Left-wing back-room extremists, Mr. Douglass considers, " will soon have to find a new pretext for letting down strikers if their manœuvrings are not to be made manifest by this moth-eaten excuse for calling off unofficial strikes just before they collapse with the weight of their own deceit."

" It is many years," Mr. Douglass points out, " since British managements were ' compelled to examine men's claims ' by responsible leadership in trade unions." That battle, Mr. Douglass affirms, is behind the unions.

" Enthusiastic demonstrations against the employer," he suggests, " may satisfy the emotions of the moment, but they will not provide homes for the people, or food for their stomachs, or refrigerators, or washing machines, or motor cars for them; and there is no reason why we should keep our sights low in making our demands on industry, if we accept the responsibilities arising as a consequence."

Mr. Douglass, who is a member of the Trades Union Congress General Council, was one of the three men appointed by the Minister of Labour to form a court of inquiry into the dispute regarding wages in the railway industry.

STEEL ERECTORS' WAGE CLAIM

The dispute concerning the claim of men engaged in the erection of steel building frames for increased rates of pay, which has been in progress for some months, seems no nearer a settlement.

Meetings of the executive council of the men's union, the Constructional Engineering Union, were held during the past week-end, and it was announced subsequently that more members of the union engaged at building sites throughout the country would cease work during the next few days, in support of the union's campaign. It was also stated that a national demonstration would take place in London on January 24.

The union asks for parity in wage rates with those paid to craftsmen in the building industry and last summer presented a claim to the Engineering and Allied Employers' National Federation for increases of 3¼*d.* an hour for men employed in the London area and of 2¾*d.* an hour for those engaged elsewhere.

The Federation rejected the claim on the ground that steel erectors did not rank as craftsmen and that, in any case, their wage rates were covered by existing agreements in the engineering industry.

DISPUTE EXTENDED

As a protest against the rejection of the men's demands, the union called a series of strikes at building sites in many parts of the country, including the West of England, South Wales, Cheshire and London. Some of these strikes are still in progress.

The Minister of Labour suggested that an investigation should be made into the dispute, but the union declined to stop strike action as a preliminary. When the claims were referred recently by the employers' Federation to the Industrial Disputes Tribunal for arbitration, the union decided not to be represented. The Tribunal resolved that the union's demand must be rejected and this award is now being considered by the union.

Earlier this month, the employers' Federation announced that it had decided to abolish all overtime and week-end work by members of the union, as from to-day, unless the union ceased its strike action at scattered building sites. This course, the Federation declared, had reluctantly been decided upon as a means of protecting its members from the " aggressive action " taken by the union.

EMPLOYEES INTO SHAREHOLDERS

An interesting provision in connection with the offer for sale of ten million one-pound ordinary shares by Colvilles Limited, is the proposal to grant interest-free loans to employees of the company to enable them to become shareholders.

The company announced last Monday that they had prepared a scheme to assist employees, aged 21 years and above, who wished to apply for blocks of 50, 100, 150 or 200 shares. It is estimated that about 17,000 of the firm's workpeople will be eligible to participate in the offer.

The loan will cover the full cost of the shares, which are being issued at 26*s.* each, and repayment will be made by deductions from the individual's salary or wages of 3*d.* a share each week for 104 weeks. In this way, employees will be able to purchase blocks of 200 shares by allowing deductions of £2 10*s.* to be made from their earnings, over a period of two years.

Colvilles Limited, is the sixth firm in the iron and steel industry to offer its shares for sale since denationalisation began. The application list, which is likely to be heavily over-subscribed, opened and closed yesterday.

CHEMICAL EMPLOYEES' WAGES

A number of demands for improved conditions in the chemical industry are likely to be presented in the near future.

An official announcement by the Chemical Workers' Union, after a meeting of its national executive committee on Monday, stated that the union had decided to demand a basic minimum wage of £8 a week for all adult male employees, with a minimum of 80 per cent. of this rate for women workers, and proportionate rates for juveniles.

The union, the announcement states, is also in favour of the adoption of a national wage policy in place of the existing system of collective bargaining. It has also decided to ask for the acceptance of the principle of equal pay for equal work.

RAILWAY WAGES

Discussions between representatives of the British Transport Commission and the three principal railway unions on rates of pay for clerical employees were resumed last Tuesday.

The progress that had been made in connection with negotiations on the wages for railway employees in the conciliation grades was reported to a meeting of the national executive committee of the National Union of Railwaymen on the same day.

There appears to be good reason for supposing that the union is generally satisfied with the progress so far made. A final settlement of the union's claims may have to await a solution of the claims of the footplate men, some of whom are members of the N.U.R. and some of the Associated Society of Locomotive Engineers and Firemen. The latter union is not yet satisfied with the offers that have been made in respect to its footplate members.

NOTICES OF MEETINGS

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LONDON
"Work of the Indian National Scientific Documentation Centre," by Joe Reid. Room 319D, Lambeth Bridge House, S.E.1. Tues., Jan. 25, 5.30 p.m.

British Institution of Radio Engineers

LONDON
"A Survey of Tuner Designs for Multi-Channel Television Reception" by D. J. Fewings and S. L. Fife. London Section. London School of Hygiene and Tropical Medicine, Keppel-street, W.C.1. Wed., Jan. 26, 6.30 p.m.

Chemical Society

BRISTOL
"Bacteriological Examination of Water," by Dr. E. Windle Taylor. Bristol Branch. Chemistry Department, The University, Bristol. Thurs., Jan. 27, 7 p.m.
CARDIFF
"Recent Advances in Photochemistry," by Professor R. G. W. Norrish. South Wales Branch. Chemistry Department, University College, Cardiff. Mon., Jan. 24, 5.30 p.m.
SHEFFIELD
"Some Naturally Occurring Polyacetylenes," by Professor B. Lythgoe. Sheffield Branch. The University, Sheffield. Thurs., Jan. 27, 7.30 p.m.
ST. ANDREWS
"Recent Advances in Acetylene Chemistry," by Professor R. A. Raphael. St. Andrews and Dundee Branch. Chemistry Department, The University, St. Andrews. Fri., Jan. 28, 5.15 p.m.

Engineers' Guild

BIRMINGHAM
"Human Relations in Industry," by R. Bramley-Harker. West Midland Branch. Engineering Centre, Stephenson-place, Birmingham. Wed., Jan. 26, 6.30 p.m.

Illuminating Engineering Society

BATH
"Lighting for Photography," by R. W. Unwin. Bath and Bristol Centre. South Western Electricity Board, Old Bridge-street, Bath. Fri., Jan. 28, 7 p.m.
BIRMINGHAM
"Shop Window Lighting," by R. C. Pennington; "Colour in Interior Decoration," by J. B. Horniblow; "Aspects of Industrial Lighting," by F. C. Johnson; and "Aspects of Museum Lighting," by N. W. Bertenshaw. Birmingham Centre. "Regent House," St. Phillip's-place, Colmore-row, Birmingham. Fri., Jan. 28, 6 p.m.
LEEDS
"The Use of Films in the Textile Industry," by Frank Hill. Leeds Centre. E.L.M.A. Lighting Service Bureau, 24 Aire-street, Leeds, 1. Mon., Jan. 24, 6.15 p.m.
LEICESTER
"Contemporary Lighting," by K. S. Morris. Leicester Centre. Offices of the East Midlands Electricity Board, Charles-street, Leicester. Mon., Jan. 24, 6 p.m.

Incorporated Plant Engineers

BIRMINGHAM
"Auto Controls for Plant," by M. C. Rogers. Birmingham Branch. Imperial Hotel, Birmingham. Fri., Jan. 28, 7.30 p.m.
LEEDS
Discussion on "Reclamation of Worn Parts: Metal Spraying." West and East Yorkshire Branch. The University, Leeds. Mon., Jan. 31, 7.30 p.m.
LIVERPOOL
"Planned Maintenance as a Contribution to Higher Productivity," by A. J. Speakman. Merseyside and North Wales Branch. Radiant House, Bold-street, Liverpool. Mon., Jan. 24, 7.15 p.m.
SHEFFIELD
"Factory Flooring Problems," by A. E. Rice. Sheffield Branch. Grand Hotel, Sheffield. Thurs., Jan. 27, 7.30 p.m.

Institute of British Foundrymen

LONDON
"Melt Quality Tests: I—Non-Ferrous." (*a*) "Academic," by Dr. V. Kondic. (*b*) "Copper Base," by A. French. (*c*) "Light Alloys," by R. Crawford. London Branch. Waldorf Hotel, Aldwych, W.C.2. Wed., Jan. 26, 7.30 p.m.
FALKIRK
"Defects in Vitreous Enamelled Castings," by E. R. Evans. Falkirk Section. Temperance Café, Lint Riggs, Falkirk. Fri., Jan. 28, 7.30 p.m.

Institute of Fuel

LIVERPOOL
"Atomic Energy," by J. C. C. Stewart. Merseyside Sub-Section. Liverpool Engineering Society, 9 The Temple, 24 Dale-street, Liverpool. Thurs., Jan. 27, 7 p.m.

Institute of Marine Engineers

LIVERPOOL
"Metallurgy in Marine Engineering," by Dr. J. E. Garside. Merseyside and North-Western Section. Old Swan Technical College, Liverpool. Mon., Jan. 31, 7 p.m.

Institute of Metals

BIRMINGHAM
"Diffusion in Metals," by A. D. Le Claire. Birmingham Local Section. James Watt Memorial Institute, Great Charles-street, Birmingham. Thurs., Jan. 27, 6.30 p.m.

Institute of Refrigeration

LONDON
"Economic Aspects of Cold Storage Design and Operation," by G. A. May. Institution of Mechanical Engineers, 1 Birdcage-walk, St. James's Park, S.W.1. Thurs., Jan. 27, 5.30 p.m.

Institute of Road Transport Engineers

DURHAM
"Tyre Development and the Use and Abuse of Tyres," by W. R. Good. North-East England Group. Royal County Hotel, Durham. Tues., Jan. 25, 7 p.m.

Institute of Welding

LEEDS
Discussion on "Automatic Welding," with film. Leeds Branch. Great Northern Hotel, Leeds. Tues., Jan. 25, 7.30 p.m.

Institution of Chemical Engineers

BIRMINGHAM
"Application of the Continuous Solid Bowl Centrifuge to the Chemical and Allied Industries," by G. D. Kelsey, at 3 p.m. Preceded by the Annual General Meeting at 2.30 p.m. Midlands Branch. The University, Edmund-street, Birmingham. Sat., Jan. 29.
MANCHESTER
"Aspects of the Chemical Processes Ancillary to Atomic Energy," by Sir Christopher Hinton, at 3 p.m. Preceded by the Annual General Meeting at 2.30 p.m. North-Western Branch. Engineers' Club, Albert-square, Manchester. Sat., Jan. 29.

Institution of Civil Engineers

LONDON
"The Employment of Unit Hydrographs to Determine the Flows of Irish Arterial Drainage Channels," by J. J. O'Kelly. Hydraulics Engineering Division. Tues., Jan. 25, 5.30 p.m.
YORK
"Prestressed Units for Short-Span Highway Bridges," by A. D. Holland. Yorkshire Association. Royal Station Hotel, York. Fri., Jan. 28, 7 p.m.

Institution of Electrical Engineers

LONDON
"Radio Aids to Marine Navigation," by Captain F. J. Wylie, R.N., retd. Radio Section. Mon., Jan. 24, 5.30 p.m.
"Sealed Transformers," by E. B. Franklin. Supply Section. Wed., Jan. 26, 5.30 p.m.
Faraday Lecture on "Courier to Carrier in Communications," by T. B. D. Terroni. Central Hall, Westminster, S.W.1. Thurs., Jan. 27, 6 p.m. Admission by ticket.
BRADFORD
Discussion on "The Scope of Protection in Higher National Certificate Syllabuses," opened by D. Fawcett. North Midland Centre. Technical College, Great Horton-road, Bradford. Tues., Jan. 25, 6.30 p.m.
NEWCASTLE-UPON-TYNE
"Design, Performance and Application of Miniature Circuit-Breakers," by H. W. Wolff and T. G. F. Atherton. North-Eastern Centre. Neville Hall, Westgate-road, Newcastle-upon-Tyne. Mon., Jan. 24, 6.15 p.m.
NOTTINGHAM
"Special Effects for Television Studio Productions," by A. M. Spooner and T. Worswick. East Midland Centre. Gas Department's Demonstration Theatre, Nottingham. Tues., Jan. 25, 6.30 p.m.

Institution of Engineering Inspection

GLASGOW
"The Application of Plastics in General Engineering," by Herbert Winning. West of Scotland Branch. St. Enoch Hotel, Glasgow. Wed., Jan. 26, 7.30 p.m.

Institution of Engineers and Shipbuilders in Scotland

GLASGOW
"Some Experiments in Oscillating Bearings," by Dr. F. T. Barwell, A. A. Milne and J. S. Webber. Tues., Jan. 25, 7.30 p.m.

Institution of Mechanical Engineers

LONDON
"Gold Mining: Surface Plant and Underground Equipment," by I. Witt. London Graduates' Section. Tues., Jan. 25, 6.30 p.m.
Discussion on "Principles Underlying the Choice of Working Stresses and the Extent to which Plasticity Can Be Used in Design." Applied Mechanics Group. Wed., Jan. 26, 6.45 p.m.
Co-operation in Engineering Research Between Educational Institutions and Industry," by Professor E. Giffen, V. C. Davies and J. H. R. Nixon. Fri., Jan. 28, 5.30 p.m.
BRADFORD
"Planning a Modern Factory," by C. M. Dolezalek. Yorkshire Branch. Technical College, Bradford. Mon., Jan. 24, 7 p.m.
BRISTOL
"Production Problems in Commercial-Vehicle Manufacture Caused by New Models," by D. L. Campbell. Western A.D. Centre. Royal Hotel, Bristol. Thurs., Jan. 27, 6.45 p.m.
IPSWICH
"Inspection, Explosion and Breakdown of Boilers and Pressure Vessels," by J. Eyers. Eastern Branch. Great White Horse Hotel, Ipswich. Thurs., Jan. 27, 7.30 p.m.
LIVERPOOL
"Recent Developments in the Road Transport and Bulk Handling of Sugar," by C. H. Williams. North-Western A.D. Centre. The University, Walker Buildings, Brownlow Hill, Liverpool. Tues., Jan. 25, 7.15 p.m.

Institution of Mining Engineers

LONDON
"Coalfields of Great Britain and Their Future Development," by E. H. Browne. Annual General Meeting. Grosvenor House, Park-lane, W.1. Thurs., Jan. 27, 11 a.m.

Institution of Production Engineers

LINCOLN
"Industrial Productivity Value of Work Study to Industry," by W. H. Hodgetts. Lincoln Section. Ruston Club, Unity-square, Lincoln. Thurs., Jan. 27, 7.30 p.m.
LUTON
"Induction Heating," by Dr. R. H. Barfield. Luton Section. Town Hall, Luton. Tues., Jan. 25, 7.15 p.m.
MANCHESTER
"Powder Metallurgy," by Dr. E. M. Trent. Manchester Graduate Section. College of Technology, Manchester. Tues., Feb. 1, 7.15 p.m.
NORWICH
"The Work of H.M. Inspectors of Factories," by H. H. Tranter. Norwich Section. Assembly House, Theatre-street, Norwich. Tues., Jan. 25, 7.30 p.m.
NOTTINGHAM
"The Measurement and Significance of Surface Finish," by R. E. Reason. Nottingham Section. Victoria Station Hotel, Nottingham. Wed., Feb. 2, 7 p.m.
READING
"Production Engineering Research," by Dr. D. F. Galloway. Reading Section. Canteen, Transport Equipment, Ltd., Worting-road, Basingstoke. Thurs., Feb. 3, 7.30 p.m.
SHREWSBURY
"Training for Production Engineering," by E. M. Price. Shrewsbury Section. Shrewsbury Technical College, Shrewsbury. Mon., Jan. 24, 7.30 p.m.
WOLVERHAMPTON
"Developments in Centreless Grinding Techniques," by Arthur Scrivener. Wolverhampton Graduate Section. Wolverhampton and Staffordshire Technical College, Wulfruna-street, Wolverhampton. Wed., Jan. 26, 7.30 p.m.

Institution of the Rubber Industry

MANCHESTER
"Use of Rubber in Pressure-Sensitive Adhesive Tapes," by J. Dow. Manchester Section. Engineers' Club, Albert-square, Manchester. Mon., Jan. 24, 6.15 p.m.

Institution of Structural Engineers

LONDON
"Brittle Fracture Problems in Steel Construction," by G. M. Boyd. Thurs., Jan. 27, 6 p.m.
BIRMINGHAM
"Influence of Welding on Steel Building Structures, with Particular Reference to Erection," by S. M. Reisser. Midland Counties Branch. James Watt Memorial Institute, Birmingham. Fri., Jan. 28, 6 p.m.
"The Use of Light Alloys in Structures," by H. V. Hill. Midland Counties Graduates' and Students' Section. Joint meeting with the Birmingham and Five Counties Architectural Association. James Watt Memorial Institute, Great Charles-street, Birmingham. Mon., Jan. 31, 6 p.m.
CARDIFF
"Simple Plastic Theory," by Dr. B. G. Neal. Wales and Monmouthshire Branch. South Wales Institute of Engineers, Park-place, Cardiff. Mon., Jan. 31, 6.30 p.m.
MANCHESTER
"Modern Architecture," by Dr. T. Howarth. Lancashire and Cheshire Branch. College of Technology, Manchester. Tues., Jan. 25, 6.30 p.m.

Junior Institution of Engineers

LONDON
"Tubular Structures," by E. McMinn. Fri., Jan. 28, 7 p.m.

Manchester Metallurgical Society

MANCHESTER
"Cathodic Protection," by Dr. W. F. Higgins. Central Library, Manchester. Wed., Jan. 26, 6.30 p.m.

Royal Aeronautical Society

LONDON
"Testing a V-Bomber," by Squadron Leader H. G. Hazelden and R. H. Williams. Graduates' and Students' Section. Tues., Jan. 25, 7.30 p.m.
"Dynamic Problems of Interplanetary Flight," by D. F. Lawden. Section Lecture. Thurs., Jan. 27, 7 p.m.

Royal Meteorological Society

LONDON
"Chemical Composition of Precipitation as a Function of Atmospheric Circulation Patterns," by Professor C.-G. Rossby. Wed., Jan. 26, 5 p.m.
"Clouds," by F. H. Ludlam. County Hall, Westminster Bridge-road, S.E.1. Thurs., Jan. 27, 5.30 p.m.

Royal Society

LONDON
"Electronic Structure and Magnetic Properties of Uranyl-Like Ions," by J. C. Eisenstein and M. H. L. Pryce; "An Electron Microscope and Diffraction Investigation of Nucleation in Silver Azide," by J. Sawkill. Thurs., Jan. 27, 4.30 p.m.

Royal Statistical Society

SHEFFIELD
"Inventory Control in Firms," by K. S. Lomax. Sheffield Industrial Applications Group. Grand Hotel, Sheffield. Thurs., Jan. 27, 6.30 p.m.

Sheffield Metallurgical Association

SHEFFIELD
Annual General Meeting. Presidential Address by T. H. Arnold. B.I.S.R.A. Laboratories, Hoyle-street, Sheffield, 3. Tues., Jan. 25, 7 p.m.

The address and telephone number of the headquarters of each institution are given below. Meetings in the headquarters town are held there unless otherwise stated. Particulars for this column should reach the Editor not later than Monday morning in the week preceding the date of the meeting.

Aslib, 4 Palace-gate, London, W.8. (WEStern 6321.)
British Institution of Radio Engineers, 9 Bedford-square, London, W.C.1. (MUSeum 1901.)
Chemical Society, Burlington House, Piccadilly, London, W.1. (REGent 0675.)
Engineers' Guild, 78 Buckingham-gate, London, S.W.1. (ABBey 7315.)
Illuminating Engineering Society, 32 Victoria-street, London, S.W.1. (ABBey 5215.)
Incorporated Plant Engineers, 48 Drury-lane, Solihull, Birmingham. (Solihull 3021.)
Institute of British Foundrymen, St. John Street Chambers, Deansgate, Manchester 3. (Blackfriars 6178.)
Institute of Fuel, 18 Devonshire-street, Portland-place, London, W.1. (LANgham 7124.)
Institute of Marine Engineers, 85 The Minories, London, E.C.3. (ROYal 8493.)
Institute of Metals, 4 Grosvenor-gardens, London, S.W.1. (SLOane 6233.)
Institute of Refrigeration, Dalmeny House, Monument-street, London, E.C.3. (MINcing Lane 6851.)
Institute of Road Transport Engineers, 69 Victoria-street, London, S.W.1. (ABBey 6248.)
Institute of Welding, 2 Buckingham Palace-gardens, London, S.W.1. (SLOane 9851.)
Institution of Chemical Engineers, 56 Victoria-street, London, S.W.1. (VICtoria 6161.)
Institution of Civil Engineers, Great George-street, London, S.W.1. (WHItehall 4577.)
Institution of Electrical Engineers, Savoy-place, Victoria-embankment, London, W.C.2. (TEMple Bar 7676.)
Institution of Engineering Inspection, 28 Victoria-street, London, S.W.1. (ABBey 3794.)
Institution of Engineers and Shipbuilders in Scotland, 39 Elmbank-crescent, Glasgow, C.2. (Central 5181.)
Institution of Mechanical Engineers, 1 Birdcage-walk, St. James's Park, London, S.W.1. (WHItehall 7476.)
Institution of Mining Engineers, Salisbury House, Finsbury-circus, London, E.C.2. (MONarch 9758.)
Institution of Production Engineers, 10 Chesterfield-street London, W.1. (GROsvenor 5254.)
Institution of the Rubber Industry, 12 Whitehall, London, S.W.1. (WHItehall 5012.)
Institution of Structural Engineers, 11 Upper Belgrave-street, London, S.W.1. (SLOane 7128.)
Junior Institution of Engineers, Pepys House, 14 Rochester-row, London, S.W.1. (VICtoria 0786.)
Manchester Metallurgical Society, The Kennedy Press, Ltd., 31 King-street West, Manchester 3.
Royal Aeronautical Society, 4 Hamilton-place, London, W.1. (GROsvenor 3515.)
Royal Meteorological Society, 49 Cromwell-road, South Kensington, London, S.W.7. (KENsington 0730.)
Royal Society, Burlington House, Piccadilly, London, W.1. (REGent 3335.)
Royal Statistical Society, 21 Bentinck-street, London, W.1. (WELbeck 7638.)
Sheffield Metallurgical Association, 15 Crescent-road, Sheffield 7. (Sheffield 53674.)